MARINE LIFE IN INDIA

The sea covers about three-quarters of the earth's surface and houses a complex and varied set of creatures, including some as colourful as butterflies and birds. There are many that have quaint, even bizarre, habits. Some fishes, for instance, can literally 'shock' you with a high voltage electric current. Others rob their prey of poison darts and store these in their bodies to use as weapons. Yet others are experts in marksmanship, and can shoot down a target with water bullets.

There are also creatures that live in the dark ocean depths, producing their own light. Then there are marine plants that do not have a root, stem, leaves or flowers, and are so tiny that ten million could fit in a thimbleful of water. Some of these marine creatures have no relatives on land or in fresh water.

Full of such fascinating facts, illustrations, and photographs, *Marine Life in India* is compact, engaging, and easy-to-read. The young reader and others with an interest in marine life will find this book a valuable introduction.

B.F. Chhapgar, a marine biologist with over fifty years' experience, has been Curator, Taraporevala Aquarium, Mumbai, and Research Officer, Taraporevala Marine Biological Station. He has also worked for the Department of Fisheries for over twenty years. During his career, the author has discovered three previously unknown species of marine crabs and two mantis shrimps. He also co-discovered a new kind of jellyfish and fish. A Life Fellow of the International Oceanographic Foundation, Miami, USA, his publications include *Seashore Life of India*, *Common Fishes of India* and *Wonders of the Deep Sea*.

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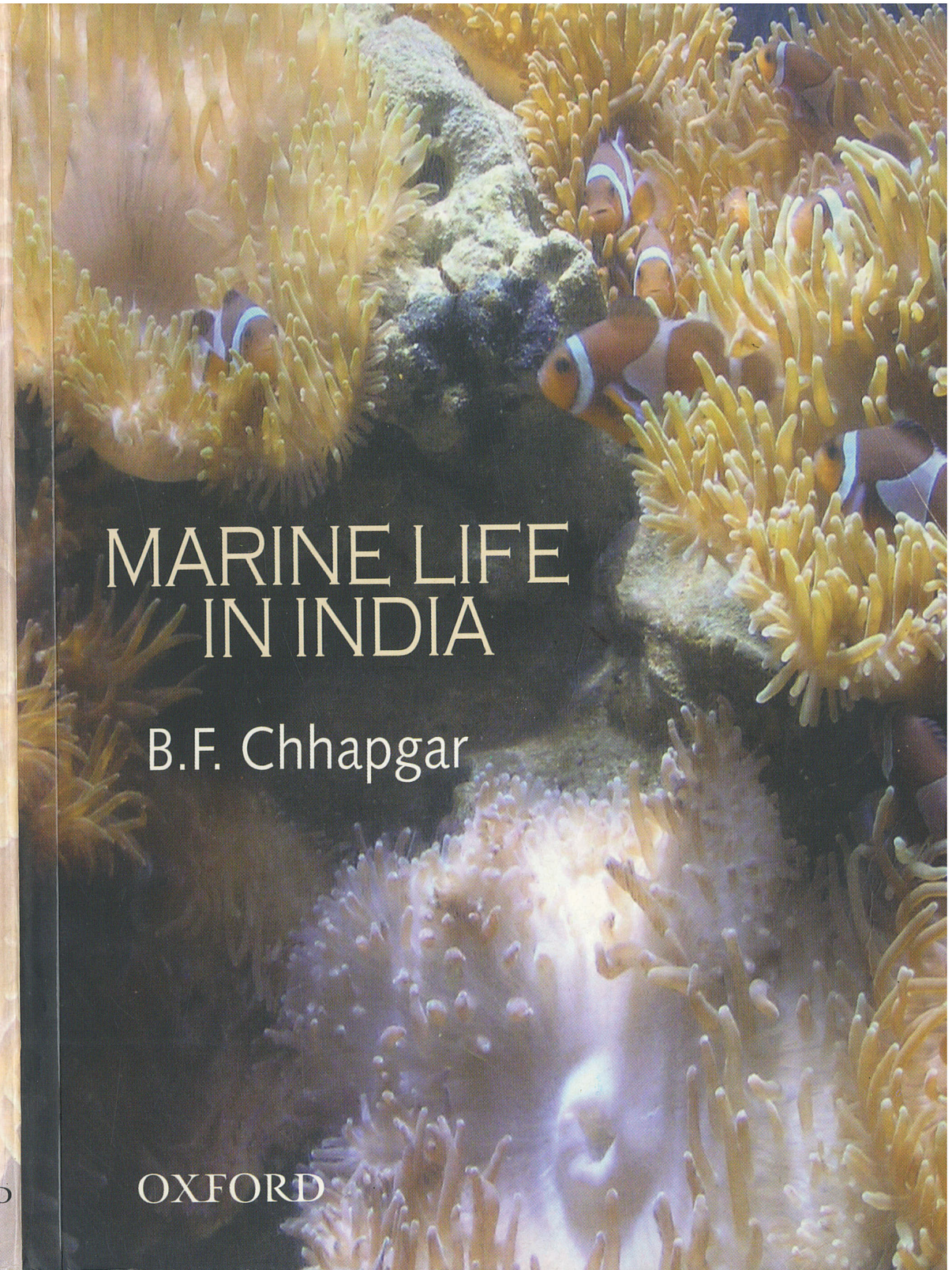
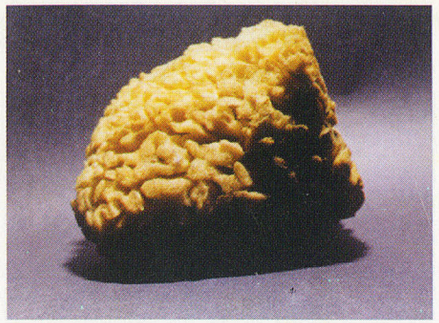


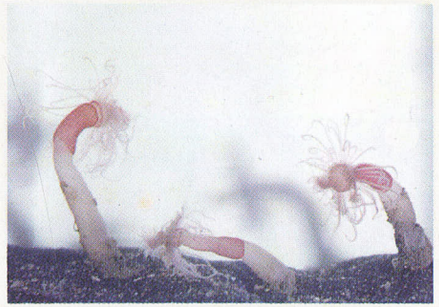
Marine Life in India

Variety is the spice of (marine) life

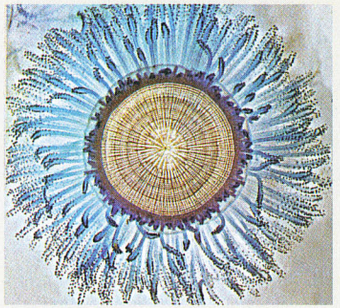


1. Bath Sponge

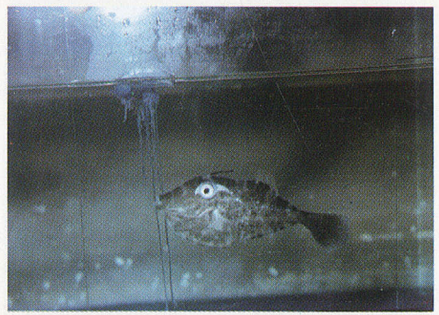
2. Sea Rose (Tubularia)[Photo: S. R. Sane]



3. Corymorpha [Photo: S. R. Sane]



4. Blue Dollar (Porpita)



5. Portuguese Man-of-war (Physalia) (on left) with a Scribbled Leather jacket feeding on it

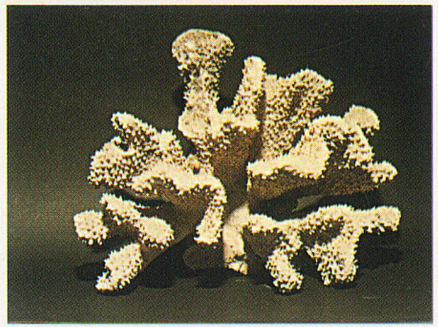
6. Sea Anemone (Paracondylactis indicus)

7. Live coral (Goniopora stokesi) from Mumbai

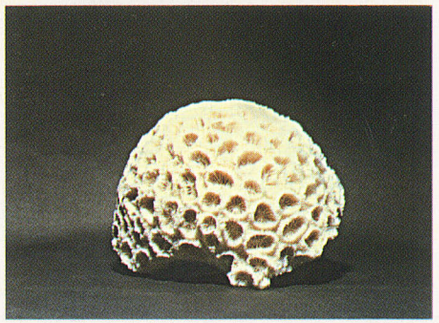
8. Live coral with extended polyps from Colaba, Mumbai

All photographs [except where specifically named] are by the author

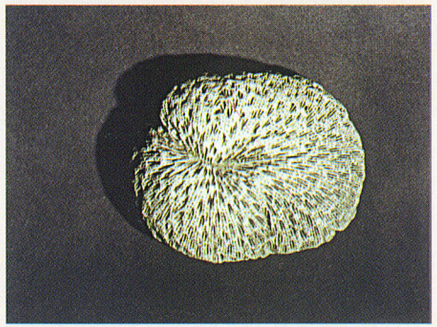
9. Staghorn coral (Acropora) skeleton



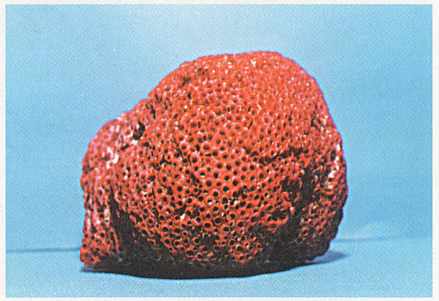
10. Finger coral skeleton



11. Star coral skeleton



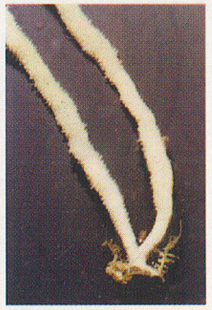
12. Mushroom coral (Fungia) skeleton



13. Organ-pipe coral (Tubipora musica) skeleton

14. Part of soft coral colony from Mumbai

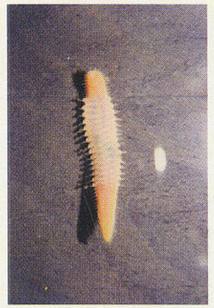
15. Toadstool-shaped soft coral polyp from Mumbai



16. Whip coral (Sea Fan)

17. Sea mat (Polyzoon) colony

18. Moss-animal (Polyzoon) colony



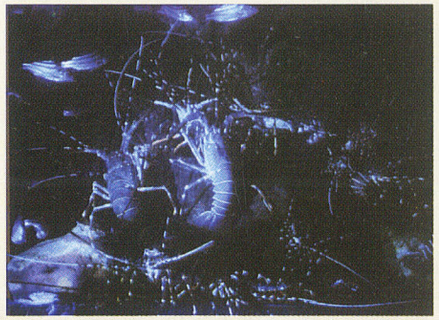
19. Polychaete worm, showing regeneration

20. Polychaete worms showing parapodia
[Photo: S.R. Sane]

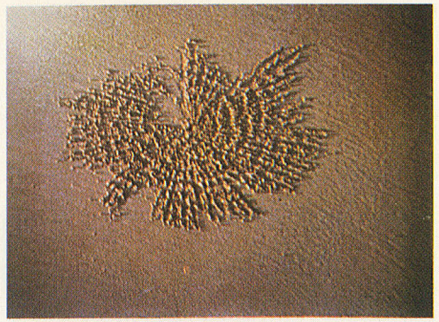
21. Brine shrimp (Artemia salina)

22. Acorn barnacles (Balanus) on a rock

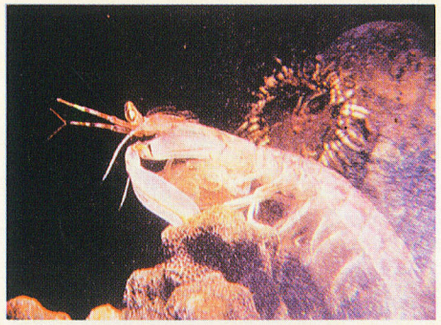
23. Pistol shrimp (Alpheus crassimanus)



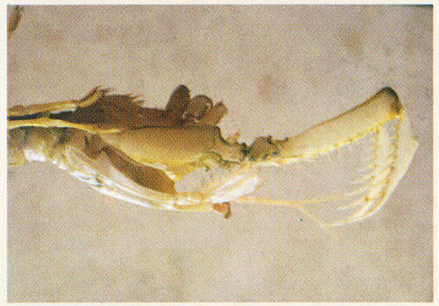
24. Spiny lobsters (Panulirus polyphagus) on a rock



41. "Sunburst" pattern of sand grains around burrow of Soldier crab (Dotilla myctiroides)



42. Mantis shrimp (Squilla), side view



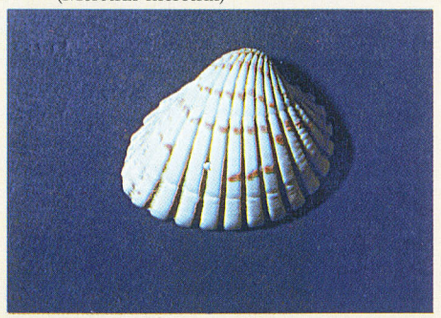
43. Head of giant mantis shrimp (Harpiosquilla raphidea) showing spiked claw

44. Horseshoe crab (Tachypleus gigas)

45. Live clam (Mya) showing long siphons [Photo: S.R. Sane]

46. Bivalves: (clockwise from left) Windowpane oyster (Placuna Placenta), Wedge clam (Donax), cockle (Cardita), Edible oyster (Crassostrea), giant clam (Tridacna gigas), mussel (Perna viridis) and Backwater clam (Meretrix meretrix)

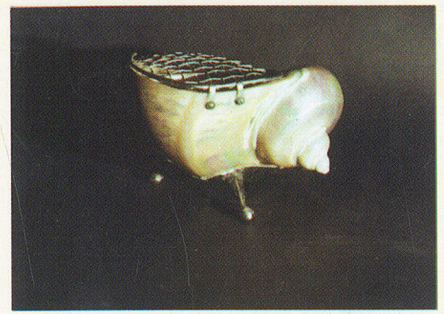
47. Inner side of valve of edible oyster



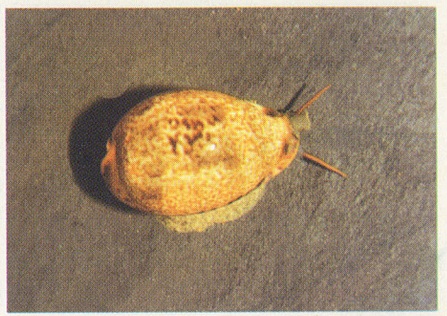
48. One valve of false cockle (Cardita asiatica)

49. One valve of giant clam (Tridacna maxima)

50. Live razor clam (Solen truncata)

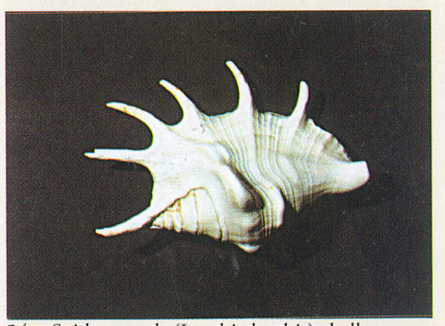


51. Souvenir made from giant turban shell (Turbo marmorata)

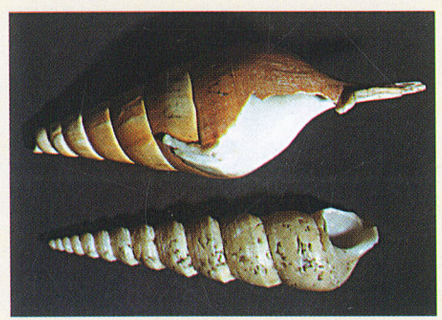


52. Live cowrie (Ovalipisa caurica)

53. Cameos made from tiger cowrie (Cypraea tigris)

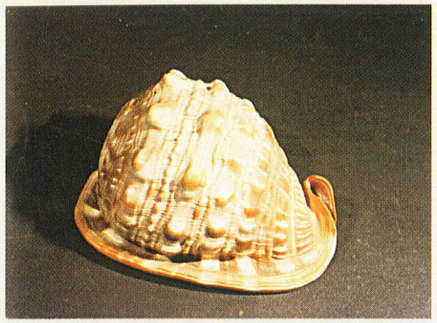


54. Spider conch (Lambis lambis) shell

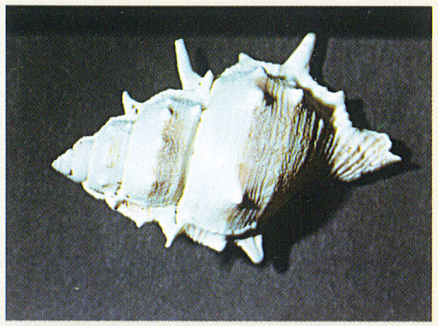


55. Indian tibia (Tibia curta) (top) and screw shell (Turritella duplicata) (bottom)

56. Spotted tun shell (Tonna dolium)



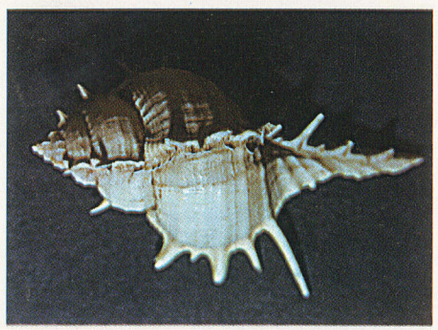
57. Helmet shell (Cypricassis rufa)



58. Spiny frog shell (Bursa spinosa)

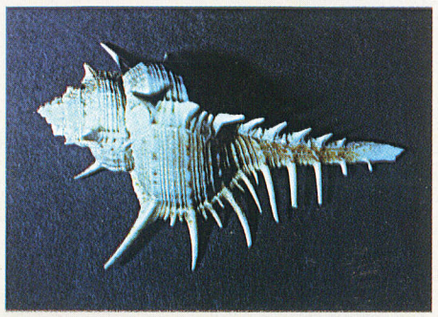
59. Neptune's trumpet (Charonia tritonis)

60. Melon shell (Melo melo)

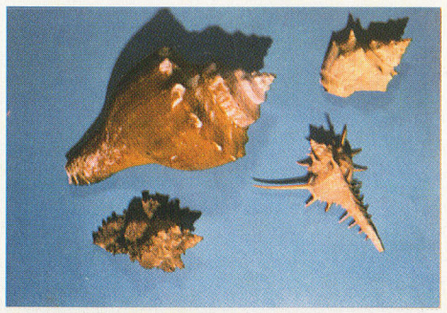


61. Murice (Murex trapa)

62. Giant murice (Murex ramosus)



63. Venus's comb shell (Murex tribulus)

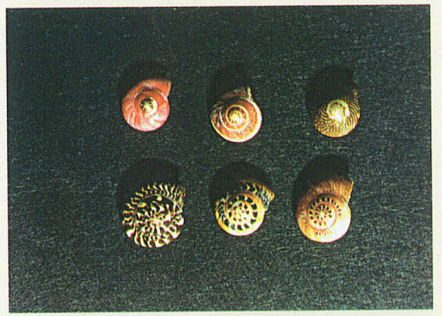


64. Clockwise from left: Hemifusus pugilinus; Thais camifera; Murex tribulus and Murex adustus shells

65. Cone shell (Consprella praecellens)

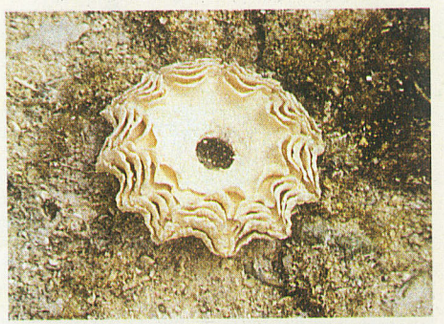
66. Harp shell

67. Ear shell (from inside)



68. Colour variations in button-shell (Umbonium vestiarium)

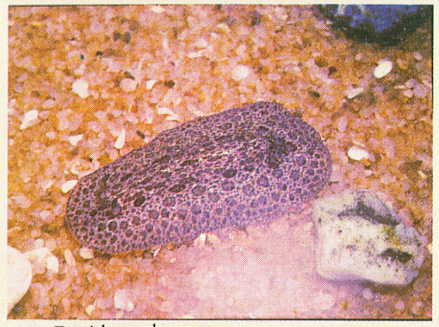
69. Phalum granulatum atop its egg capsules



70. Egg case of Uber snail
[Photo: K. Rustomji]

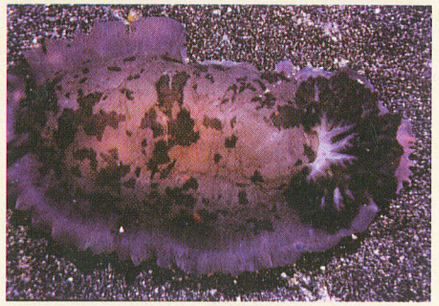
71. Armina, upper and lower side
[Photo: S.R. Sane]

72. Green sea hare (Elysia grandifolia)
[Photo: S.R. Sane]



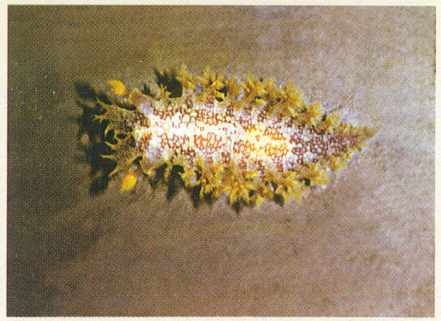
73. Dorid sea slug

74. Polka-dotted dorid sea slugs
[Photo: S.R. Sane]

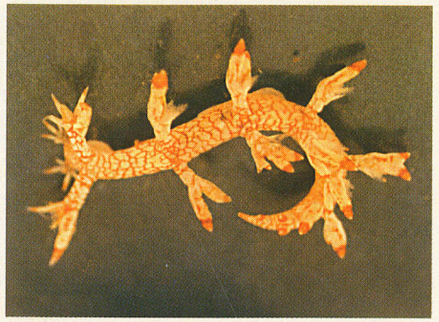


75. Giant dorid sea slug [Photo: S.R. Sane]

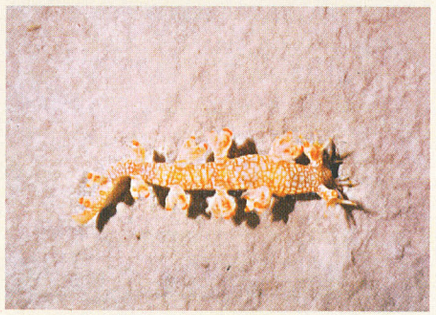
76. Hairy gilled aeolid sea slug
[Photo: S.R. Sane]



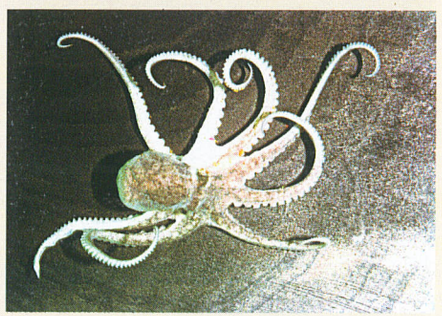
77. Lace gilled aeolid sea slug from Mumbai



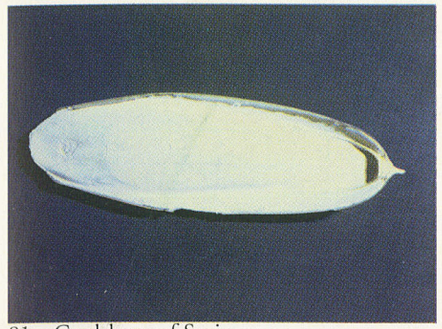
78. Nipple gilled aeolid sea slug from Mumbai



79. Stub gilled aeolid sea slug from Mumbai

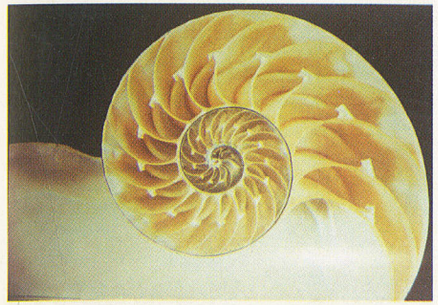


80. Octopus

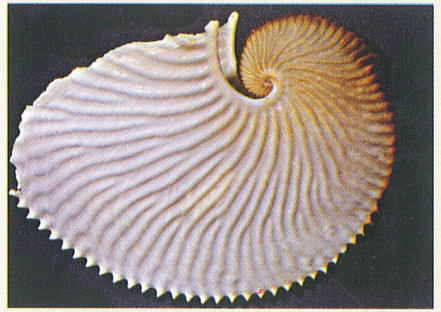


81. Cuttlebone of Sepia

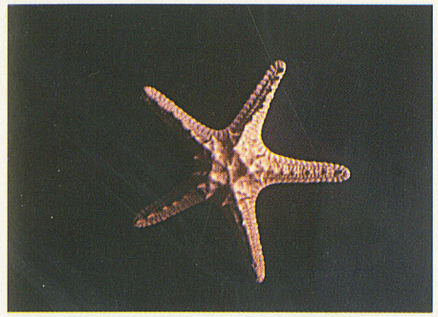
82. Pearly nautilus shell



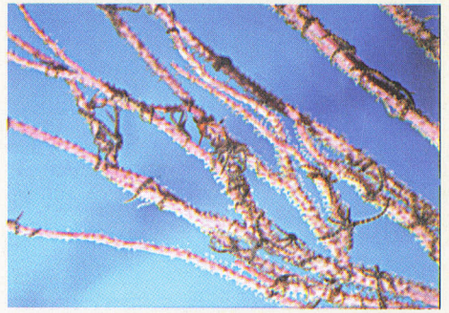
83. Pearly nautilus shell, cut to show chambers



84. Female paper nautilus shell
(Argonauta argo)



85. Thorny sea star



86. Brittle stars (Ophiothela danae) on sea fan

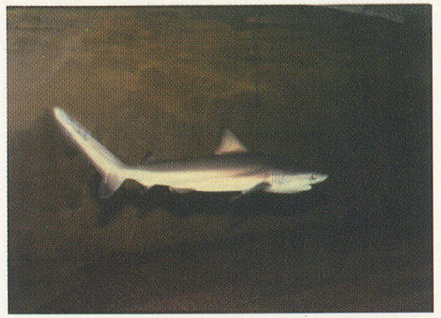
87. Two sand dollars [Photo: S.R. Sane]

88. Black sea cucumber (Holothuria scabra)

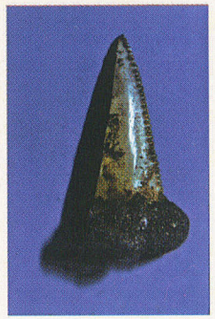
89. Red sea cucumber [Photo: M.R. Almeida]

90. Bushy sea cucumber

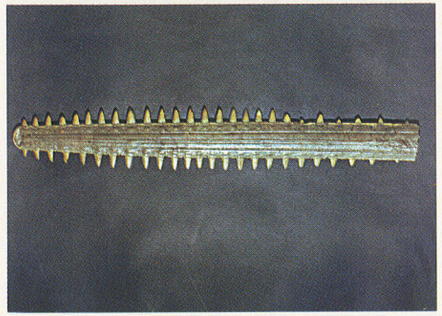
91. Sea cucumber throwing out sticky threads from organ of Cuvier [Photo: K. Rustomji]



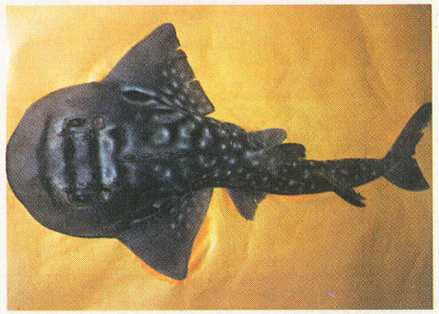
92. Sharp nosed shark [Photo: R.V. Ranade]



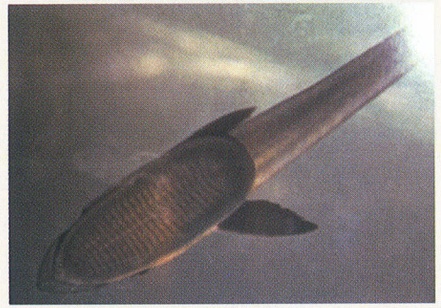
93. Semi-fossilised shark tooth from centre of manganese nodule at sea bottom



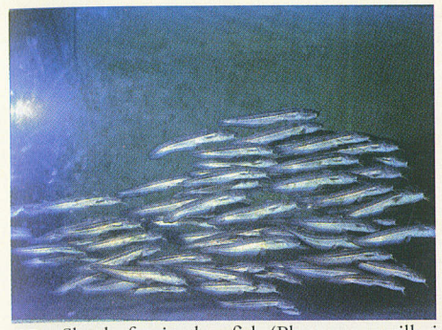
94. Snout of sawfish (Pristis)



95. Bow-mouth guitarfish [Photo: V.N. Hegde]

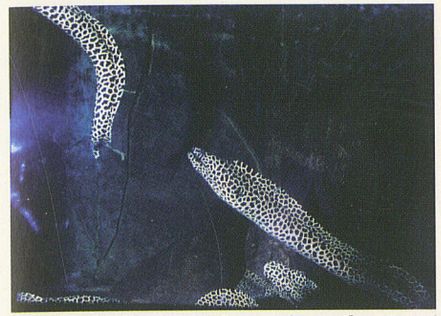


96. Head of suckerfish

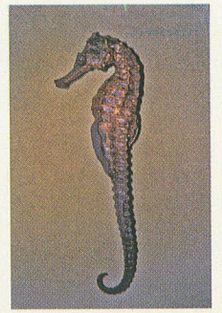


97. Shoal of striped catfish (Plotosus anguillaris)

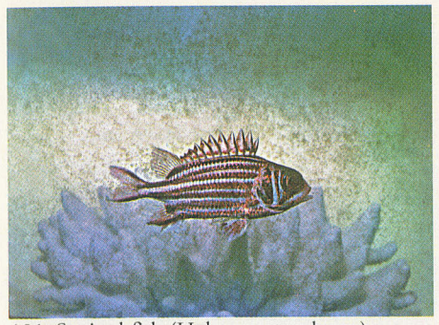
98. Closer view of striped catfish



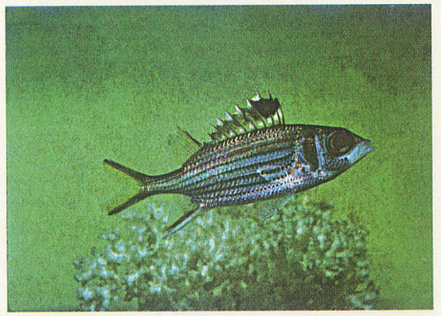
99. Marbled morays (Gymnothorax favagineus)



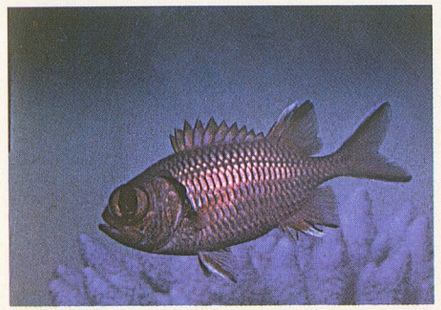
100. Sea horse (Hippocampus kuda)



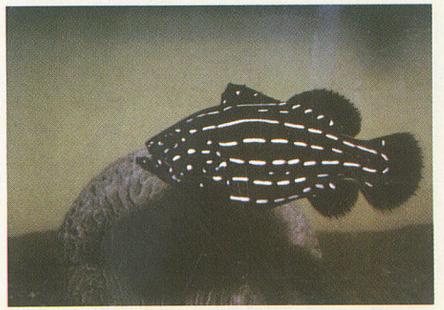
101. Squirrel fish (Holocentrus rubrum)



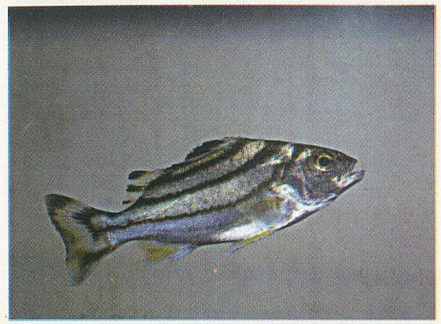
102. Japanese squirrel fish



103. Soldier fish (Myripristis murdjan)

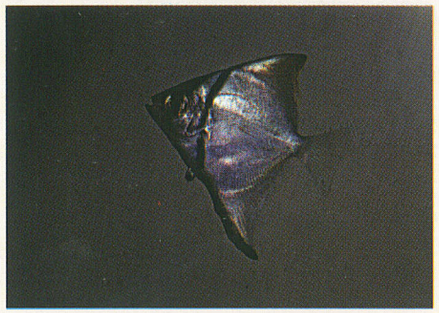


104. Thread-and-needle fish (Grammistes sexlineatus)

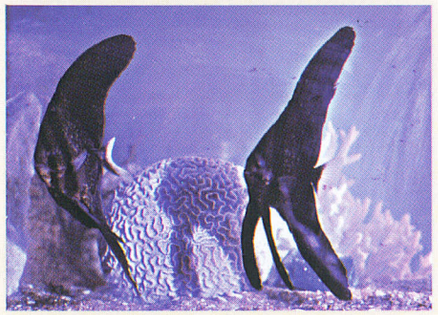


105. Target perch (Terapon jarbua)

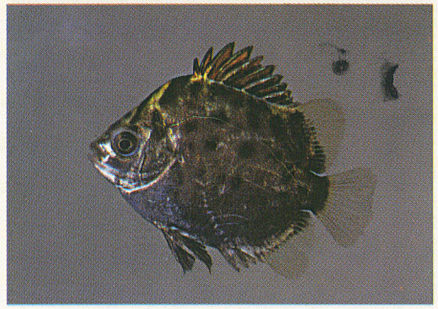
106. Zebra sweet lips (Gaterin lineatus) (above) and squirrel fish (below)



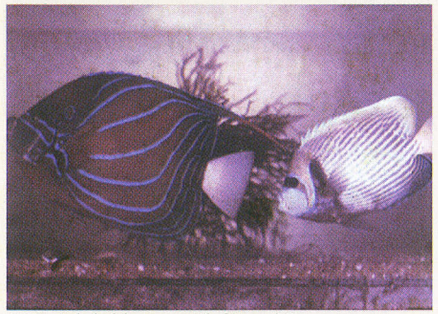
107. Ceylon angel (Monodactylus argenteus)



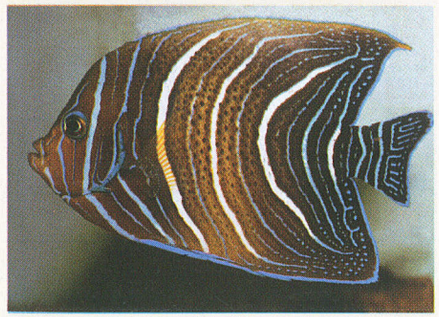
108. Batfish (Platax teira)



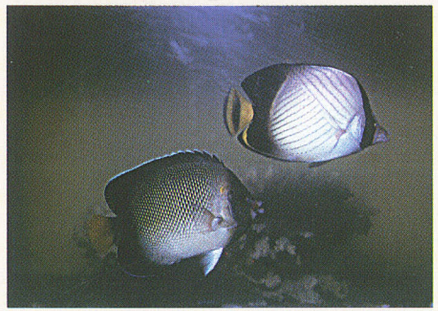
109. Scat (Scatophagus argus)



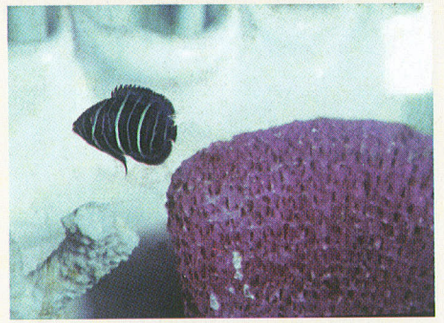
110. Adult blue ring (left) and Emperor angelfish (right)



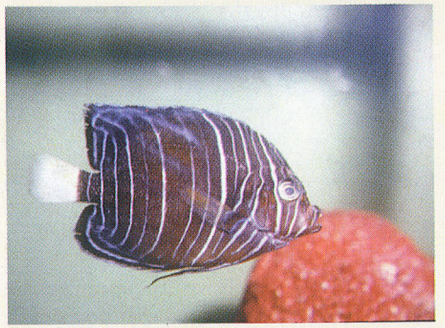
111. Juvenile Koran fish (Pomacanthodes semicirculatus)



112. Mimicry: Butterfly fish (above) and Angelfish (below)

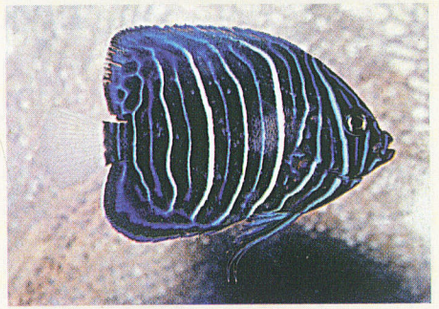


113.



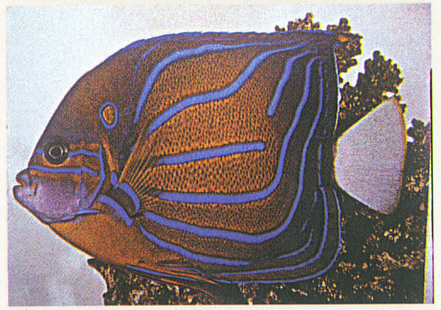
114.

Sequence of colour changes from baby through juvenile to adult of Blue-ring angelfish (113 to 117)

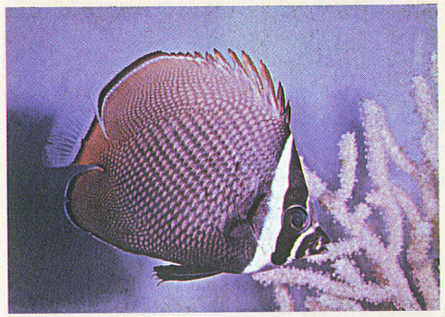


115. Blue-ring angelfish from Mumbai

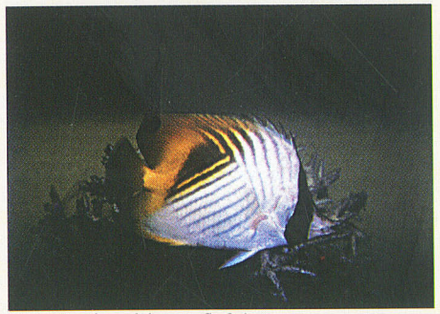
116. Blue-ring angelfish



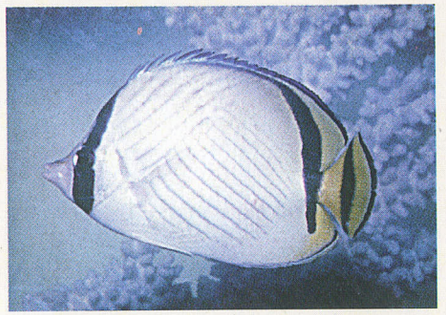
117. Blue-ring angelfish



118. Collared butterflyfish (Chaetodon collare)

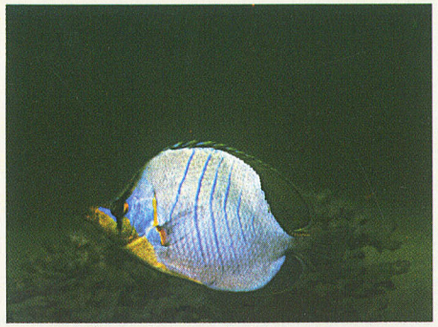


119. Vagabond butterflyfish (Chaetodon vagabundus)

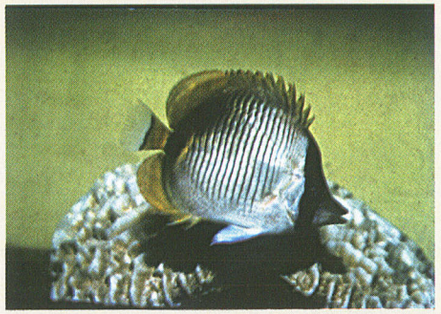


120. Yellow-brown butterflyfish (Chaetodon pictus)

121. Chevroned butterflyfish
(Chaetodon trifasciatus)



122. Saddle-back butterflyfish
(Rhabdophorus xanthocephalus)

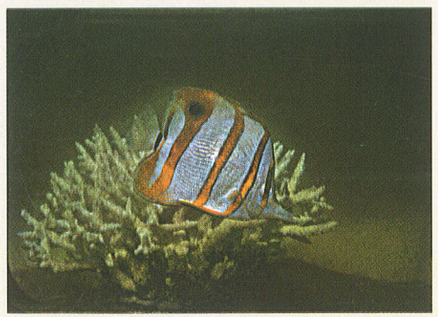


123. Lined butterflyfish (Oxychaetodon lineolatus)

124. Threadfin butterflyfish (Chaetodon auriga)
Note: "False eye"

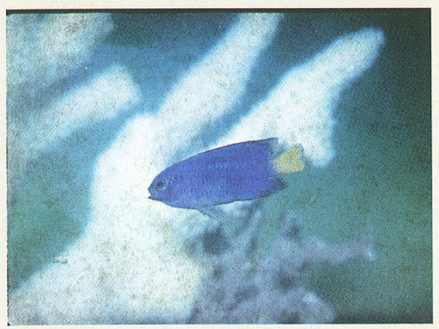
125. Racoon butterflyfish (Chaetodon lunula)

126. Pennant bannerfish (Heniochus acuminatus)

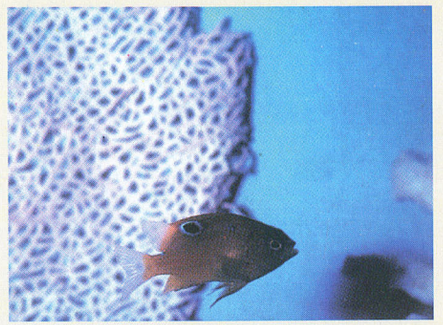


127. Copper-banded coralfish (Chelmon rostratus)

128. Pearlspot or Green chromide
(Etroplus suratensis)



129. Yellow-tailed blue damselfish
(Pomacentrus caeruleus)



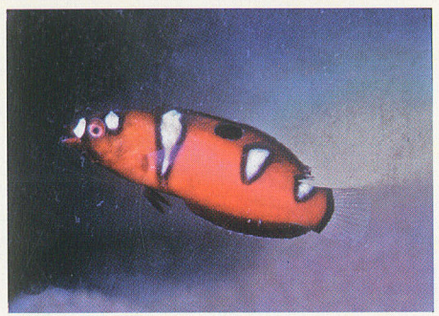
130. Ocellated damselfish [Photo: S.R. Sane]

131. Swallowtail damselfish

132. Sergeant major (Abudefduf saxatilis)

133. Chequerboard wrasse (Thalassoma hebraicum)

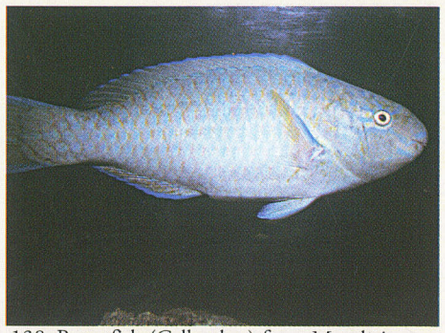
134. Banded wrasse (Thalassoma hardwicki)



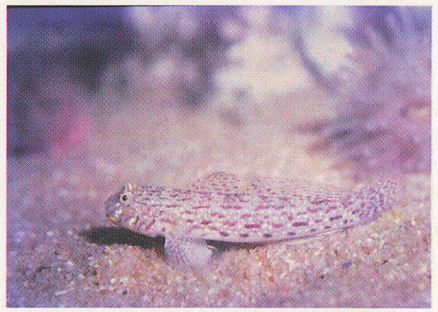
135. Juvenile Clown wrasse (Coris gaimard)

136. Cleaner wrasse (Labroides dimidiatus)

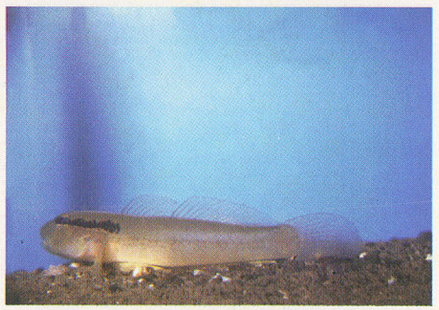
137. Club-nosed wrasse (Gomphosus varius)



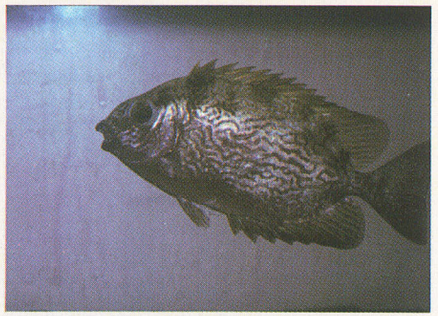
138. Parrotfish (Callyodon) from Mumbai



139. Morse-code goby (Istigobius ornatus)

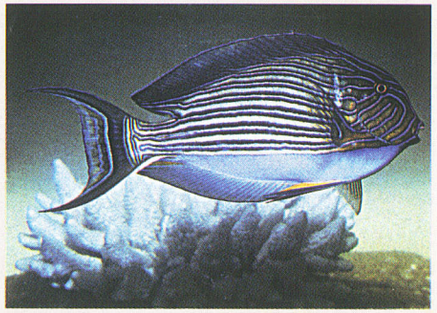


140. Airliner goby (Acanthogobius diadema)

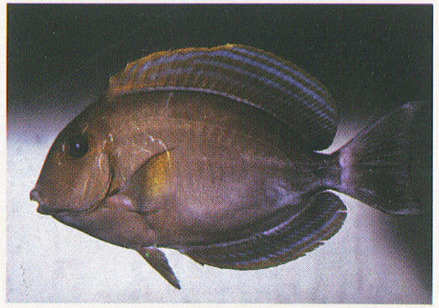


141. Jigsaw-puzzle rabbitfish (Siganus vermiculatus)

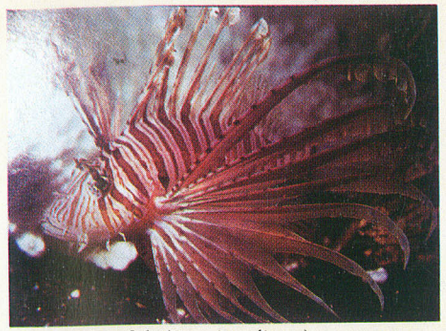
142. Blue surgeon fish (Acanthurus leucosternon)



143. Striped surgeon fish (Acanthurus lineatus)

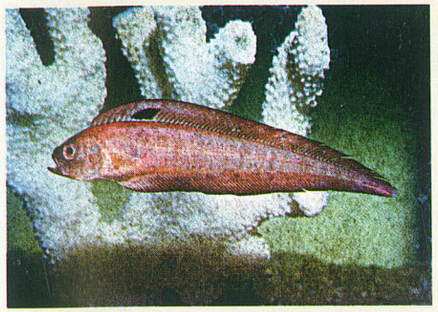


144. Slender-toothed surgeon fish (Acanthurus strigosus)

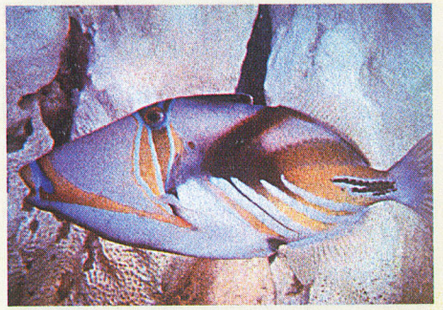


145. Turkey fish (Pterois volitans)

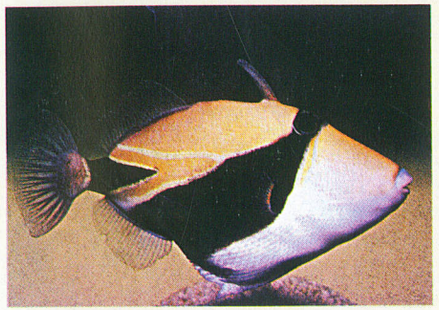
146. Stone fish (Synancaea horrida)



147. Copper streak (Cepola indica)

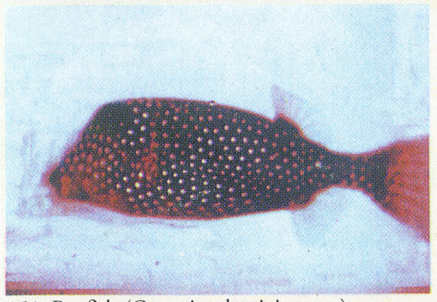


148. Picasso triggerfish (Rhinecanthus aculeatus)

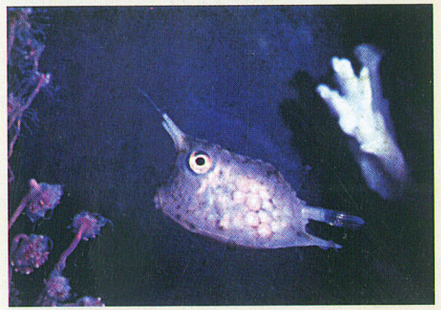


149. Wedge-tailed triggerfish (Rhinecanthus rectangulus)

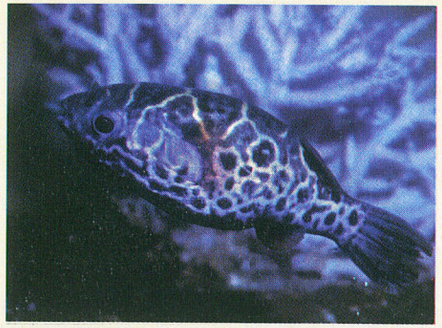
150. Scribbled leatherjacket (Alutera scripta)



151. Boxfish (Ostracion lentiginosum)

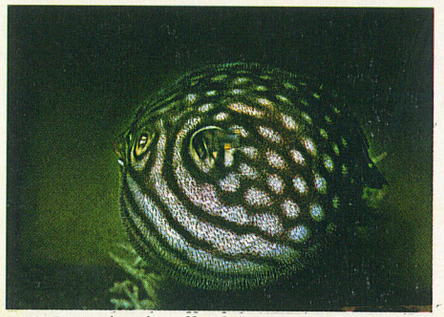


152. Cowfish (Lactoria cornuta)
[Photo: S.R. Sane]



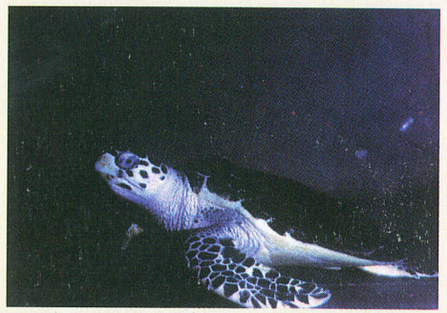
153. Estuarine puffer fish (Chelenodon fluviatilis)

154. White-spotted puffer fish (Arothron hispidus)

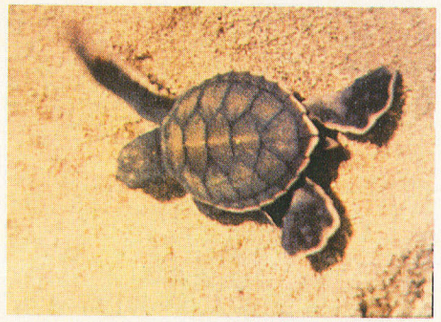


155. Reticulated puffer fish (Arothron reticularis) (inflated)

156. Angler fish (Antennarius hispidus)



157. Loggerhead turtle (Caretta caretta)



158. Newly-hatched sea turtle

159. Banded sea snake (Hydrophis cyanocinctus), stranded on sea shore [Photo: Varad B.Giri]

160. Author, with fish catch [Photo: Rodney Jonklass]

Marine Life in India

B.F. CHHAPGAR

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This book is dedicated to my mother Banubai,
who at first tolerated and
then actively encouraged
my love for the sea

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Foreword

Known as a source of food (fish, salt, gelatine) and as a passage for transport from continent to continent since time immemorial, the great potential of the seas to meet future human needs in medicines, minerals and in harnessing energy has been revealed recently. On the academic front, the monsoon, the very pulse of Indian economy, is shown to be dependent on the sea-surface temperature. The secrets of climate-vegetation changes over the millennia and also the archaeological scenarios of the past are brought out through the pollen grains of plant species and certain algae getting deposited in marine sediments.

I, for one, never get tired of looking at the sea in its multifarious moods: stormy, choppy in monsoon; calm, placid in winter; framed with bright colours at summer sunset. That this very sea and its immediate vicinity is home to a variety of fascinating animal beings is brilliantly brought out in this book by Dr B.F. Chhapgar, an eminent marine biologist of international fame and a prolific writer who has to his credit nine books and over a hundred popular and technical papers written to popularize science in a style that is appealing to the lay person.

A precocious youngster, Dr Chhapgar graduated at the age of 17 when most of the students of this age are still in school. He has been associated with the Taraporevala Aquarium, Mumbai, for 22 years, right from its inception in 1951, and was its Curator from 1959 to 1965, as well as Research Officer-in-Charge of the Taraporevala Marine Biological Station wherefrom he has gleaned his practical knowledge.

Far from being an easy-chair biologist, Dr Chhapgar has qualities of an explorer. An experienced scuba-diver and mountaineer and trekker, he has participated in the International Indian Ocean Expedition twice and in the inaugural cruise of Ocean Research Vessel *SAGAR KANYA*, among many others. The result is the discovery of seven species new to science and several new records for India. His career has been dotted with awards and honours: Scholarships from Government of Bombay State, Vicaji Taraporevala Trust, Life Fellowship of International Oceanographic Foundation, Rotary Club of Bombay Seacoast Lifetime Achievement Award, Dharmakumarsinhji Trophy being some of the outstanding acknowledgments of his worth and calibre. The Smithsonian Institution, Washington, has acknowledged the sterling contribution made by this dedicated, committed person by having his portrait hung in their gallery of Crustacea. Incidentally, he is one among only two Indians to receive this rare honour. And he has been the only Indian to be on the editorial board of two prestigious international magazines brought out from USA.

At a time when global warming, climate change, rising sea levels, beach erosion, cyclones ravaging heavily populated coastal areas are making headlines as major environmental problems, the author's timely warning of preventing harmful anthropogenic activities will go a long way towards conserving biodiversity and maintaining sustainable uses of resources.

I have great pleasure in writing these lines as a foreword to the work of the author, a man who has shunned personal publicity, whom I met personally only a few years back but whose scientific works I had repeatedly come across.

—V.M. Meher-Homji
Former Dean,
Salim Ali School of Ecology,
Pondicherry University

Preface

Forests at the bottom of the sea – the branches and leaves,
Sea-lettuce, vast lichens, strange flowers and seeds – the thick
Tangle, the openings, and the pink turf,
Different colours, pale grey and green, purples whites and gold –
The play of light through the water,
Sluggish exigencies grazing there, suspended, or slowly crawling
Close to the bottom: The sperm whale at the surface,
blowing air and spray, or dissporting with her flukes,
The leaden-eyed shark, the walrus, the turtle, the hairy sea-leopard,
and the sting ray,
Passions there, wars, pursuits, tribes – sight in those ocean depths –
Breathing that thick breathing air, as so many do.

—Walt Whitman
THE WORLD BELOW THE BRINE

When one contemplates the vastness of knowledge gathered about the sea, it is expected that there would be a plethora of books on the subject. There are quite a few of these, but most of them are written in a highly technical language and are targeted to the advanced serious student at the graduate, or higher, level. The ordinary person does not want to devote a lifetime to the study of the life in the sea, hence the need for a compact book written in an easy-to-follow style which will give a glimpse of sea life, awaken curiosity, satiate the need to gain a better picture and to tread the long path, if need be, to a more detailed study of that major portion of the earth's surface which is covered by water. I agree with Herman Melville that "there is, one knows not what sweet mystery about the sea, whose gently awful stirrings seem to speak of some hidden soul beneath."

To undertake the task of dealing with so huge and complex a topic as life in the sea in a single book is a challenging venture as many volumes are usually written to do full justice. But voluminousness and a high level of technical language would defeat the purpose of developing "sea consciousness" in the reader who has no technical background to topics covered herein. That is why I do not desire to follow a style dense with footnotes and heavy on academic jargon that takes some effort to extract the author's intended meaning from the fog of verbiage. For this reason, I have avoided, as far as possible, using scientific names. At the same time, I do not wish to emulate George Bernard Shaw who, tongue in cheek, used the word "ghoti" for fish. His explanation: pronounce 'gh' as in enough, 'o' as in women, and 'ti' as in fiction! I am acting only as a communicator, who gives an opportunity to the reader to read and ponder, to wonder at the many mysteries of the sea, and to develop a deeper understanding of it.

To make for light reading, I have thought fit to start each topic with a poem appropriate to it. It was when I started browsing through poetry books that I realised the vast store of poems written about the sea and its creatures. In fact, like Robert Louis Stevenson's confession,

> Of all my verse,
> like not a single line;
> But like my title, for it is not mine.
> That title from a better man I stole;
> Ah, how much better, had I stolen the whole!

The reader may be intrigued – nay, even frightened – at seeing the vast number of "chapters", numbering over seventy. Each so-called chapter covers a topic, and it is not over four or five pages, though a few have perforce to be extended to more pages. There is an intrinsic advantage in this brevity; it does not permit the reader to get bored, as each chapter ends by the time his attention starts to wander.

It was with some trepidation that I started this book, but I was inspired by Don Carlos, who says, "Nothing would ever be written if a man waited till he could write so well that a reviewer could find no fault with it." I was also encouraged by D. Molloch's lines:

> If you can't be a pine on the top of a hill,
> Be a scrub in the valley – but be
> The best little scrub by the side of the rill,
> Be a bush if you can't be a tree.

So what I have done is just to emulate Kipling's monkeys, viz.,

> All the tales I ever have heard
> Uttered by bat or beast or bird –
> Hide or skin or scale or feather –
> Jabber it quickly and all together.

I believe it is far better to attempt to write something, however badly, instead of just sitting tight, again like Kipling's monkeys:

> Here we sit in a branchy row,
> Thinking of beautiful things we know;
> Dreaming of deeds that we mean to do,
> All complete in a minute or two –
> Something noble and grand and good,
> Won by merely wishing we could.

And from where did I manage to get this heterogeneous information? Like Rudyard Kipling,

> Some I gathered from my friends
> And some I looted from my foes,
> And some – all's fish that Heaven sends –
> Are histories of private woes.

And, though I may have had the good fortune of having close connections with the sea for half my life and having been a keen student of sea life, as Isaac Newton says, "I do not know what I may appear to the world, but to myself I seem to have been like a boy, playing on the seashore, and dwelling myself, in now and then finding a smooth pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me."

It is said that William Faulkner wrote a novella during a single shift on his job as a night watchman. I am not such a genius; it took me some years to gather material and describe it, and my apologies to those who waited patiently for me to complete the task.

The material gathered in this book is genuine; I did not create it. It is but the cream skimmed from much whey of unsuccessful toil and curds of disappointment. It has been derived partly from my personal experience of over fifty years, but a sizeable portion has been culled from books and technical "Papers" too numerous to list. For anyone who wishes to expand his knowledge, a short list of books which will be of interest to the general reader is included at the end of this book.

To those who find the topics in this book very diverse and seemingly unconnected, I can only reason that I have emulated Lewis Carroll's Walrus who considered that among subjects to be talked about were shoes, sealing-wax, cabbages, kings and whether pigs have wings. I only hope that I am not like those of our countrymen in the 10th century who, according to Alberuni, "could expound extensively on subjects that they knew absolutely nothing about." I hope I am not one among those described by Charles Churchill:

> So loud each tongue, so empty was each head,
> So much they talked, so very little said.

As has been rightly said, marine zoology is the study of marine animals and not merely the study of books about them. So I cannot too strongly urge that, for true appreciation, a living animal is preferable to a dead one, and a dead one is better than any drawing or written description.

While admitting my indebtedness to Mother Nature for inspiring me, there is one thing I would like to humbly request to the reader who frequents the seashore. In one's thrill at so many new sights and enthusiasm to study them in more detail at one's leisure, there is sometimes the temptation to collect specimens and bring them home. Remember, very few people have the expertise, and the facilities, to keep marine plants and animals alive for more than a few days; most of them are dead within hours.

As Emerson has so poignantly penned it:

I wiped away the weeds and foam,
I fetched my sea-borne treasures home.
But the poor unsightly noisome things
Had left their beauty on the shore,
With the sun and the sand and the wild uproar.

Youngsters often bemoan that the days of adventure – cowboys and Red Indians, pirates and explorers, are gone. Also gone are the days when, as Longfellow admonished: "Would'st thou ... learn the secrets of the sea? Only those who brave its dangers comprehend its mysteries." But there is one frontier which is not yet fully explored, that of Science.

We need not be prophets of doom like Henry D. Ellsworth who, way back in 1844, said, "The advancement of the arts from year to year taxes our credulity and seems to presage the arrival of that period when further improvements must end." A lot of water has flowed under the bridge since then, but new discoveries and inventions show no sign of coming to an end.

Young discoverers need not despair. Scientists speculate there may be ten million species that are yet to be discovered. Recent research suggests that some 90 per cent of the earth's plants and animals still remain to be described and named. Discoveries are still tumbling out of Mother Nature's lap; if we keep our eyes open and have a curious mind, success will follow. And the secret of success?

Our terrors and our darknesses of mind
Must be dispelled, not by the sunshine's rays,
Not by those shining arrows of the light,
But by insight into Nature and a scheme
Of systematic contemplation.

So, instead of treating the study of marine life as mundane work, take it up with passion and enjoy it. When you love your work, you will excel at it. And it does not take years and years. I discovered three new animals when I was just twenty! Now I hold that

half the art of writing a preface, as of telling a story, lies in knowing when to stop, so I shall stop. But not before succumbing to the temptation of doing so with a final homage, in the form of an "Address to the Ocean" by S.W. Procter:

O thou vast Ocean! ever-sounding sea!
Thou symbol of a drear immensity!
Thou thing that windest round the solid world
Like a huge animal which, downward hurled
From the black clouds, lies weltering and alone,
Lashing and writhing till its strength be gone.
Thy void is like the thunder, and thy sleep
Is as a giant's slumber, loud and deep.
Thou speakest in the south and the west
At once, and on thy heavily-laden breast
Fleets come and go, and shapes that have no life
Or motion, yet are moved and meet in strife.
The earth hath nought of this; no chance or change
Ruffles its surface, and no spirits, dare
Give answer to the tempest-wakened air;
But o'er its wastes the weakly tenants range
At will, and wound its bosom as they go:
Ever the same, it hath no ebb, no flow;
But in their stated rounds the seasons come,
And pass like visions to their wonted home;
And come again, and vanish; the young
Spring looks ever bright with leave and blossoming;
And Winter always winds his sullen horn,
When the wild Autumn, with a look forlorn,
Dies in his stormy manhood; and the skies
Weep, and flowers sicken, when the summer flies.
Oh! wonderful thou art, great element:
And fearful in thy spleeny humorous bent,
And lovely in repose; thy summer form
Is beautiful, and when thy silver waves
Make music in earth's dark and winding caves,
I love to wander on thy pebbled beach,
Marking the sunlight at the evening hour,
And hearken to the thoughts thy waters teach –
Eternity – Eternity – and Power.

B.F. CHHAPGAR

1 Introduction

The earth is full of Thy riches;
So is this great and wide sea,
Wherein are things creeping innumerable,
Both small and great beasts.
There go the ships:
There is the Leviathan,
Whom Thou has made to play therein.
Psalm *civ*

Over two-thirds of the earth's surface is covered by water. One of the continuing concerns of man has been to understand and explore this vast watery domain. Yet, being a terrestrial creature, Man has a tendency to know more about the life and phenomena on land. Of course, the cliché that man knows more about the surface of the moon than he does of the bottom of the ocean is no longer true. Yet it has taken immense patience and an arduous task to reach our present level of understanding of the sea.

When it comes to marine life, many of us have vague –even wrong – ideas. Man's imagination, from ancient times, has run wild when it came to a study of natural history, whether on land or in the sea. As a poet has aptly written,

Those who greedily pursue
Things wonderful instead of true;
That in their speculations choose
To make discoveries strange news;
And natural history a gazette
Of tales stupendous and far-fetched;
Hold no truth worthy to be known,
That is not huge and overgrown,
And explicate appearances,
Not as they are, but as they please;
In vain strive Nature to suborn,
And for their pains are paid with scorn.

Thus the Chinese envisaged a dragon as an animal with the head of a camel, the eyes of a hare, the ears of a bull, the horns of a stag, the neck of a snake, the belly of a frog, the scales of a fish, the paws of a tiger and the talons of an eagle. An exaggeration of the early history of mankind? Then come to the recent (1757) book by Abbe de Guyon in the East Indies, where he cites Ctesias's account of a manticore. This monster had the face and ears of a man, blue eyes, a red body of the bigness, shape and strength of a lion. It had three rows of teeth with which it devoured both man and beast. Its tail, a cubit (about 50 cm) in circumference, was stuck all over with darts 30 cm long and hard as iron, which it shot forth behind and before to a hundred paces, and against whose poison there was no remedy. One cannot but admire the inventive powers of men through the ages!

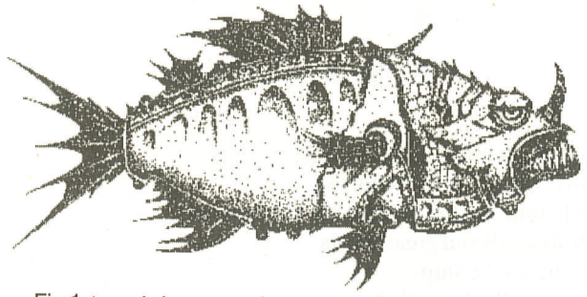


Fig.1 **An artist's concept of an imaginary manticore -like beast**

He many a creature did anatomize,
Almost unpeopling water, air, and land,
Beasts, fishes, birds, snails, caterpillars, flies
Were laid full low by his relentless hand.
Makenside *The Virtuoso*

Then there is the account of a bird in India which lives in the midst of flames without the least hurt. Clothes are made from its feathers, and all one has to do to wash them is to put them in the fire for a short time. Had this been a reality, our dhobis (washermen) would be jobless!

More down to earth is a species of ant as big as a fox, which has the property of finding out where gold is buried, and digs it up. Equally interesting, as it touches on marine life, is Abbe's account of flying fish: In summer it flies upon the mountains, and after autumn it takes itself to the sea and becomes very delicate. After reading such accounts as these, one feels that the study of nature's creatures has become a tame affair compared to what it was in the good old days.

Unless one actively searches for them, plants and animals in the sea are relegated to the background in our range of conception as compared to the more familiar ones on land. There are no large trees to inspire our awe, nor—as lay people often think—animals comparable to, say, elephants or tigers. Few people are aware of the beauty and grace of marine life. Fewer still try to understand their way of life, or why they behave as they do. Many books on the sea exist. As Aristotle said, "Each of us adds a little to our understanding of Nature, and from all the facts assembled arises a certain grandeur." Then again, as Chuangtzu said, "You cannot speak of the ocean to a well-frog, the creature of a narrower sphere." But surely there are many of us who would like to learn more about the sea but are daunted by what they deem to be gobbledygook full of scientific jargon in most books meant for technically advantaged scientists. In comparison, there is a dearth of books on the sea aimed at the intelligent lay reader interested in expanding his view of the sea and its mysteries. For, as W.R. Inge puts it so succintly, "it is a scandal that anyone should be bored in this interesting world."

The works of human artifices soon tire
The curious eye; the fountain's sparkling rill,
And gardens, when adorned by human skill,
Reproach the feeble hand, the vain desire.
But oh! the free and wild magnificence
Of Nature in her lavish hours doth steal,

In admiration silent and intense,
The soul of him who hath a soul to feel.
Longfellow

With some misgivings I have endeavoured to fill this gap in India's popular science literature. Scientists may criticise, as they have the right and the duty to do, whatever they consider the technical faults of the book, but they should remember that they are in some measure to blame for not writing such a book themselves. The marine world is not the sole prerogative of the technically trained; the lay person also has a right to be considered. The purpose of science is knowledge, and every one has the right to know. What science has discovered is common property and should be made easily available to all.

I have here only made a garland of culled flowers, and have brought nothing of my own but the thread that ties them together. And I make no apologies for being selective about the information included in this book. Writing a book that is both academically "respectable" (and hence acceptable by one's peers) and yet comprehensible to lay persons not familiar with the subject is one of the most difficult tasks facing any author. It is hoped that the format and style chosen in this book will be an effective compromise to meet both objectives. The format and layout should enable both biologists and lay persons to quickly absorb the contents, which will tell them what is known of their habits, behaviour and general biology. I hope that those who know marine biology better than I do, will not find the book inaccurate and that those who have never been and may never be on the sea will, through its medium, obtain something like a vital impression, a living picture of some of the most attractive and interesting forms of life.

A humble word of caution. A college degree does not always mean that one is educated. It implies that one has been opened up to a perpetual state of ignorance and thus an innate curiosity and a lifelong thirst for more knowledge. And as far as my state of knowledge is concerned, I feel that I am still like a child, looking at this extraordinary world with round eyes. There is so much I must learn; everything arouses my curiosity. I have one main interest, and that is to know more about it. And, according to Browning, how God laughs when any man says, "Here I'm learned: this I understand". So, like John Masefield (in SEA-FEVER):

I must down to the sea again, for the call of the running tide
Is a wild call and a clear call, that may not be denied;
And all I ask is a windy day with the white clouds flying,
And the flung spray and the brown spume, and the sea-gulls crying.

I am fortunate to live near the sea, and it has influenced my whole outlook on life. It made me feel awed and humble. If you lived on the sea, you could not help comparing everything with it, and it has made everything—money, power and fame—puny. The sea gives me a richness and independence that no one can take away from me. (As with Binod Rao), the horizon prompts strange thoughts of the unknown, unseen forces at work ceaselessly night and day. Yes; no other single phenomenon, not even the towering mountain heights perhaps arouses the same overpowering sense of the eternal and the infinite. For the mountains, however high they may be, are of the earth, tapering off and ending somewhere, even if we cannot mark their tops with our human eyes. But the sea, the awesome sea—who knows whence it comes and where it may lead?

A word of caution. In the rather ill considered rush we make to exploit our marine resources, we have taken little trouble to examine the capabilities and possibilities of the sea's wild creatures, save insofar as the findings were of commercial value. Therefore much that is interesting has been overlooked. The kinship between man and the rest of our natural flora and fauna becomes very apparent to those of us who sojourn on the sea for any length of time; alarmingly so to those whose attitude has been governed by the well-worn and much abused phrase that "Man shall dominate over all." For, as Joachim Miller so accurately puts it,

> The course of life is like the sea;
> Men come and go, tides rise and fall,
> And that is all of history.

The idea of domination and submission, though now passing out of fashion in nearly every walk of life, is still hard to dissociate in the minds of (fortunately) a few. For the enlightened person, the sea is a harmonious element in the general "landscape" that is incomparable in its nobility of colour, mass and a feeling of the Unchangeable. Dominance? Conquest? The sea is never conquered; one makes friends with it. Man never dominates it, but belongs there as do the skies, sunshine and other living creatures, keeping time with the seasons, moving in an orderly procession with Nature, holding to the unity of life in all things, seeking no superior place for himself but merely a state of harmony with all created things. Remember, Man is supplicant to, rather than master of Nature. So

> Be lenient with lobsters, and ever kind to crabs,
> And be not disrespectful to cuttlefish or dabs;
> Be tender with the tadpole, and let the limpet thrive,
> Be merciful to mussels, don't skin your eels alive;
> When talking to a turtle don't mention calipee
> Be always kind to animals wherever you may be.

Nothing is more unfeeling than ignorance, and nothing makes a person more compassionate towards our little fellow creatures than a close aquaintance with them. As Coleridge notes,

> He prayeth well who loveth well
> Both man and bird and beast.
> He prayeth best who loveth best
> All things both great and small;
> For the dear God who loveth us,
> He made and loveth all.

Now the sea is only a part of Nature, and it has often taken a heavy toll of lives and property. Does that mean that the sea –and, an extension of it, Nature itself – is unhappy with its children? Man has always looked upon Nature as an indulgent mother and made demands, often unreasonable, on her patience and resources. But is that image right, or is she simply an indifferent spectator who could not care about the sufferings of her creatures? Pliny the elder was the first to doubt nearly 2,000 years ago. "It is far from easy to determine whether she has proved a kind parent to man or a merciless stepmother", he said. Poets and thinkers have tried hard to fathom her. Cowper thought Nature is but a name for an effect, whose cause is God. Pope equated nature with art.

Samuel Daniel thought nature is above all art. Wordsworth, an incurable lover of nature, sang,

> Nature never did betray
> The heart that loved her.

Henry Fuseli went to the other extreme: "Nature puts me out." Poets like Tagore and Wordsworth saw an all-pervasive spirit in nature which they worshipped. In recent times, nature, particularly vegetation, has come under relentless attack by man, along with the sea, the earth and the mountains. Milton has the last word: "Nature, she hath done her part; Do thou but thine."

2 The Living Soup—Pastures of the Sea

O, what an endless worke I have in hand,
To count the Sea's abundant progeny.
Whose fruitful seeds farre passeth those in land,
And also those which wonne in the azure sky!
For much more eath to tell the starres on hy,
All be they endless seeme in estimation,
Than to recount the Sea's posterity;
So fertile be the floods in generation,
So hugh their numbers, and so numberlesse their nation.

On land, we are familiar with flowering plants such as trees, shrubs and grasses. These have roots to anchor themselves to the ground as well as absorb nutrients from the soil, and leaves containing the green pigment chlorophyll which, in the presence of sunlight convert water, carbon dioxide and simple inorganic minerals and make their own living tissues containing various sugars, starches, fats and proteins.

The land plants grow fixed to the ground. Plants in the sea which live thus fixed are the seaweeds. But, as water is not so transparent as air, light can only reach them if they are in shallow water, down to about 200 metres. At greater depths, light would be too dim for the plants to carry out photosynthesis. Most plants in the sea have, therefore, evolved a strategy of floating in the upper reaches of the sea. And, instead of taking in nutrients by means of roots, they absorb them from all over their body. Now, the smaller an organism, the more area it has in relation to its volume. Both to maximise the rate of absorption of nutrients and to minimise their weight (to prevent sinking), plants in the open sea are minute, microscopic and single-celled.

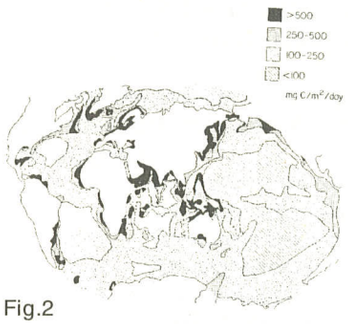


Fig.2
Phytoplankton distribution in the sea, expressed as primary production [mg. of carbon/ sq.m./day] [After Koblentz-Mishke *et al.*]

It was the Danish biologist A.S. Orsted who, on a voyage from Denmark to the West Indies in 1847, collected sea water and kept it in glass aquaria on the ship. He noticed a greenish discolouration in the water and examined the water under a microscope. He was astonished to see myriads of tiny plant forms floating therein. The German scientist Hensen coined the word "phytoplankton" to describe these tiny plants, from the Greek words *phytos* (= plant) and *plankton* (= to wander).

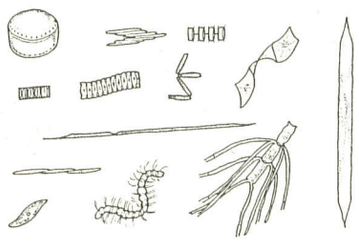


Fig.3
Various planktonic algae [After Hardy]

Popularly called diatoms are the members of the class Bacillariophyceae (of the order Chrysophyta). They are divided into two groups based on their shape—the Centric diatoms or Centrales, and the Pennate diatoms or Pennales. In both, the body is enclosed between two valves. In the Centrales, it is round, oval, triangular or square, and looks like a pill-box or a set of Petri dishes the "lid" or tap valve (called epitheca) being slightly larger and overlapping the "box" (or hypotheca). The two halves together form the frustule, which is hardened with hydrated amorphous silica ($SiO_2.nH_2O$, of which sand is made) up to 0.1 micron thick. (A micron is one-thousandth of a millimetre.) The valves are fastened together by two connecting bands which overlap one another to form the girdle. Centric diatoms show two different shapes; when the lid or bottom is viewed (valve view), and the girdle view from the side. The valves are decorated with ornate and intricate patterns of pits, perforations or striations.

Pennate diatoms are shaped like spindles, needles or are hair-like. The pattern on their frustule is in the form of two series of rows, one on either side of a line running down the middle. Most of them have a groove, called raphe, running longtitudinally along the centre of the valve, between the two series of rows of dots. (In the Centric diatoms, there is no raphe.) Both the valves may have a raphe. If there is a raphe on only one valve, it is always on the valve touching the substrate. (Some diatoms creep on the bottom mud or stones.)

When seen from the side (girdle view), the difference between the Centric and Pennate diatoms disappears; both look oblong in shape.

Inside the valves is the protoplasm containing packets of chlorophyll called chloroplasts. The green colour of chlorophyll is masked by other pigments such as beta-carotene (reddish) and xanthophylls (yellow) so that the diatoms appear yellow, olive-green or brown.

Over 9,000 species of diatoms are known. They are more abundant near the coast where rivers bring in abundant nutrients like nitrates and phosphates. A litre of sea water contains hundreds of thousands of diatoms.

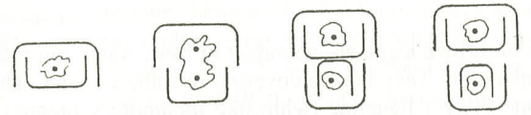


Fig.4 **Cell division in a diatom**

Diatoms multiply by dividing into half. The "box" portion then grows a new smaller half, the original box now becoming the lid, while the lid portion grows a new (and smaller) box. With each division, the size of the diatom becomes smaller, until they become perceptibly smaller after a few generations.

The sequence of cell division is shown below:

Cell Size	A [Largest]	B	C	D	E	F [Smallest]	Total number of cells
Parent Cell	1						1
1st division	1	1					2
2nd division	1	2	1				4
3rd division	1	3	3	1			8
4th division	1	4	6	4	1		16
5th division	1	5	10	10	5	1	32

Sooner or later the original size of the diatom is restored by a process called auxospore formation, where a new diatom is formed, its size being equal to the maximum size for the species.

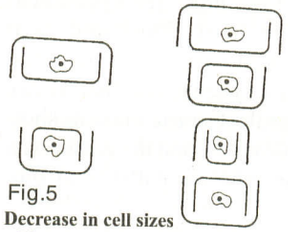


Fig.5
Decrease in cell sizes with repeated cell divisions

Diatoms occur both in the sea and in fresh water as well as in soil. Those having raphe are found on mud or stones. Diatoms without a raphe are especially abundant in fresh water plankton, while marine diatoms are mostly Centric. Some diatoms stick to each other to form colonies and may be mistaken for brown algae. After death, the frustules sink to the sea bed to form, ultimately, diatomaceous earth (kieselguhr). As Tripoli powder, this is used for polishing and for dentifrice. Because of their very fine markings diatoms are also used to test the resolving power of microscopes.

Unlike animal plankton, planktonic (floating) diatoms have no power of locomotion. They can live and grow only as long as sunlight reaches them for photosynthesis, a maximum of 200 metres. To decrease the rate of sinking, the shell is very thin, the space between the strands of protoplasm is filled by a clear fluid of the consistency of sea water, and there may be oil globules in the body. Many diatoms have long spines which, by friction, resist sinking. They can also exchange heavier seawater ions for lighter ones. The upward mixing of water currents also helps them to float in the upper layers of the sea. Diatoms are most abundant around 50 metres below the sea surface and are more abundant in the cold waters of high latitudes.

The other two classes of the order Chrysophyta are the microscopic yellow-green algae (Xanthophyceae) and golden-brown algae (Chrysophyceae). The former are the well known zooxanthellae which live in symbiotic association with animals like *Noctiluca*, sponges, corals and other coelenterates. (Microscopic green algae, the Chlorococcales, living in a similar association with animals are called zoochlorellae.) Abundant in fresh water, a few yellow-green forms live in estuaries, on the surface of the mud and in intertidal and shallow seas.

The golden-brown algae are abundant in fresh water, but a few marine forms are found in nannoplankton. They have a covering of minute scales. They are motile due to possession of one or two flagellae (whip-like locomotory organs). Some have a third flagellum-like structure called a haptonema, but this is used for attachment rather than for swimming.

Fig.6 **Some coccoliths [highly magnified] [after Braarud *et.al*]**

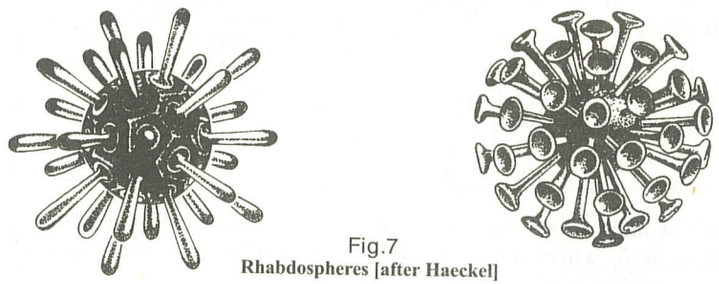
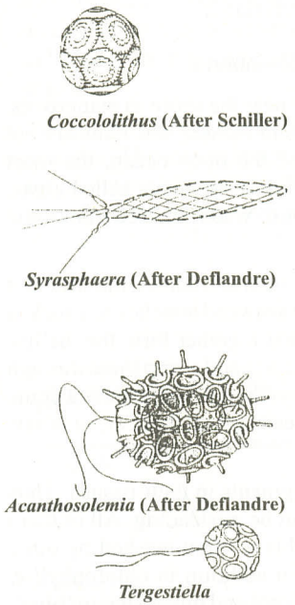


Fig.7
Rhabdospheres [after Haeckel]

Another group among the golden-brown algae are the coccolithophores. Coccolithophores are smaller than even the tiny diatoms. Coccoliths beautifully patterned calcareous plates the size of bacteria (1 to 35 microns) lie on the ocean floor and were known to geologists who were intrigued about their origin. While oval plates were called coccoliths, rod-shaped ones were known as rhabdoliths. Sir John Murray dipped fine silk threads in a glass of sea water and found that tiny creatures, now called coccospheres and rhabdospheres, clung to the threads. The plates, which may be round, oval, rod- or club-like, or barrel- and trumpet-shaped, cover or stick out from the living cell which contains brownish yellow pigments.



***Coccolithus* (After Schiller)**

***Syrasphaera* (After Deflandre)**

***Acanthosolemia* (After Deflandre)**

Tergestiella

Fig.8 **Some coccolithophores:**

Coccolithophores exhibit a lot of plasticity (flexibility). Even in the same species, coccoliths may be present or wanting; in the latter case, a flagellum may be present or absent. They sometimes reproduce in such large numbers as to produce a "bloom" seen as chalky water of a milky green colouration containing as many as 108 billion cells per litre. Unlike the blooms of blue-green algae which cause "red tide" resulting in mass mortality of fishes, coccolithophore blooms are good for fish.

Other members of the golden-brown algae are the minute (10 to 15 microns) silicoflagellates, with an internal skeleton made of silica. Only a few marine species are found in the phytoplankton.

Phytoplankton make their own food with the help of sunlight; they are called "producers" and form the food for tiny zooplankters which, in turn, are eaten by larger animals. Thus we have a food chain starting with plants and ending with the final consumers such as sharks, whales or man. Now, all the food that is consumed is not used for growth of our body parts; almost 90% is utilised for an animal's energy requirements. Hence it is estimated that out of ten units of food consumed by an organism, only one goes for its growth. We then have a pyramid of life, with many producers at its base and culminating in very few apex consumers. This requires a huge amount of phytoplankton to be present in the sea, and is achieved by the prolific breeding of these organisms called "turnover".

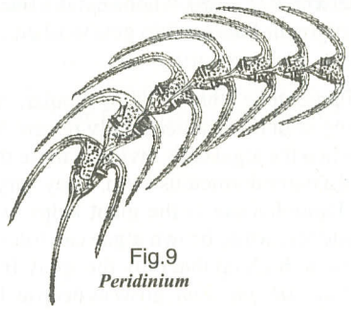


Fig.9
Peridinium

3 Forests in the Sea

At the sea-down's edge between windward and lee,
Walled around with rocks as an inland island,
The ghost of a garden fronts the sea.

Swinburne

Trees, as we know them on land, occur in the sea only near the shore as mangroves. Even flowering plants occur only in shallow littoral zones, and mosses and ferns are not found in the sea. Apart from the drifting phytoplankton of the open ocean, the most abundant plants fixed to the sea bottom are primitive non-flowering plants called algae, popularly known as seaweeds. But algae are also found in fresh water, on tree trunks and even in hot springs at temperatures of 85° C.

Unlike higher plants whose body is divided into roots, stem and leaves, the structure of algae is simple. We can distinguish a holdfast by which the seaweed attaches to a rock, a stalk or stipe, and an expanded blade or lamina. All these parts together form the thallus. Land plants have roots that absorb water and minerals from the soil and pump these through vascular bundles to the leaves which take in carbon dioxide from the air. Sea water is a dilute solution containing all these materials, so the immersed seaweeds get all these at, so to say, their doorstep.

Algae are classified according to the predominant pigments in their tissues. Thus we have blue-green, brown and red algae. But these terms can be misleading. All of them contain the green photosynthetic pigment chlorophyll, but this is often masked by other pigments. In the blue-green algae, for example, there are, in addition to chlorophyll-*e,* various carotenes and xanthophylls, as well as phycoerythrin (red) and phycocyanin (blue). "Blue-green" algae living in deep water may become red. Red Sea is so called because "blooms" (caused by population explosion) of the so-called "blue-green" alga *Trichodesmium erythraeum* (which is actually red) often impart a red tint to the sea water. (In the Pacific Ocean, a patch of these algae some 51,777 square kilometres has been seen.) Red algae, when exposed to very bright sunlight, may become purple, brownish red, green or even yellow. And the brown seaweed called bladderwrack (*Fucus*), when kept in a bucket of water for a few hours, turns green, as the brown pigment fucoxanthin gets washed out, exposing the green chlorophyll.

Even the shapes of seaweeds vary from filamentous (thread-like), tubular, fan-shaped, bladder-like and even, as in gulfweed, having structures superficially resembling stems and leaves. The basic shape is a filament but, when the algal cells divide in more than one plane, the result is a flat, expanded thallus, called a parenthymetous form. They vary in size from microscopic forms like the diatoms and Dinophyceae to the giant kelps, with fronds 30 m long. Red algae prefer a submerged existence, while brown algae can tolerate brief exposure to air at low tide. But some algae grow so high up that only the spray from waves crashing on the shore can reach them. Others, like *Lithophyllum*, grow as deep as 120 m. Their holdfasts may take the form of "apteres" or, sometimes, a bigger or smaller disc. Those living on sandy bottom have much-branched, hair-like rootlets to fasten them to sand grains.

The blue-green algae are a very primitive group. Their pigments are not contained within packets called chloroplasts, but are dispersed throughout the outer layer of cytoplasm. There is no nucleus, only a central body which controls the cell's activities. Of about 1,500 species (in 500 genera), most live in fresh water, others in the soil. Most marine forms are found near the mouths of rivers in the intertidal zone, or in the tropics, and live on or in other algae (e.g. *Richelia intercellularis* in the diatom *Rhizosolenia*). Some are endolithic, i.e., they burrow into corals, while still being capable of photosynthesis.

The cell wall is usually made of two layers. The outer gelatinous sheath contains pigments. If the pigments are fuscorhodin and fuscochlorin, the alga appears yellow or brown; with gleocapsin it appears red or violet. Together with the other pigments such as chlorophyll-*a*, phycoerythrin-*c* (red) and phycocyanin-*c* (blue) which are inside the cells, the combination can give rise to a range of colours, but they are usually a dull blue-green.

The protoplasm contained inside the firm inner cell wall layer also has outer and inner portions. The outer chromoplasm contains pigments as well as granules of a carbohydrate called cyanophycean starch and protein granules called cyanophycin. The inner colourless portion of the protoplasm, called central body, contains chromatin, the substance found in the nucleus of cells of other plants and animals.

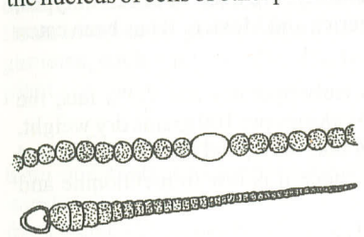


Fig.10 *Anabena* (top), *Rivularia* (bottom)

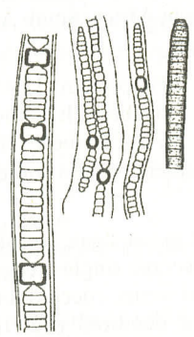


Fig.11 *Nodularia* (extreme left), *Hormothamnion* (middle), *Trichodesmium erythraeum* (extreme right). (After Iyengar & Desikachary)

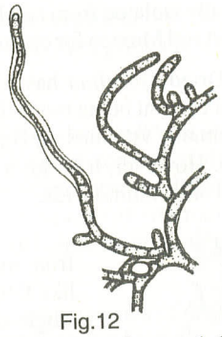


Fig.12 *Mastigocoleus* , a shell boring alga. (After Iyengar & Desikachary)

Blue-green algae reproduce by the cell dividing into two, and the daughter cells sticking together by the gelatinous sheath surrounding the cell, to form a filament like a string of beads, a flat plate, hollow sphere or a shapeless mass. A single row of cells in a filament is called a trichome. Many algae have either a gliding motion of the whole trichome; in others the end of a trichome may move like the wagging tail of a dog. Some specialised cells at intervals along a trichome are larger and transparent; these are called heterocysts. A trichome often breaks at a heterocyst into short chains called hormogonia, which then move away from the parent colony to establish a new colony.

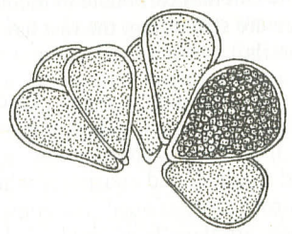


Fig.13 Endospores of *Dermocarpa*

Some cells in a filament store food reserves, enlarge and develop a thicker cell wall to form non-motile resting spores called akinetes. These may remain viable for as many as 70 years to tide over unfavourable conditions, but can germinate to form new filaments when better conditions return. Others (comprising the Chamaesiphonales) produce endospores, within which the cell divides many times to form a large number of cells.

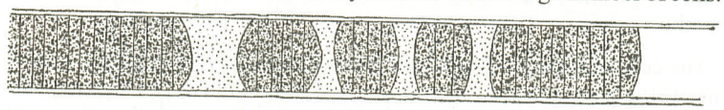


Fig.14 ***Lyngbya*, the stinging seaweed**

The filamentous blue-green alga *Lyngbya* is also called the Stinging Seaweed. Commonly found tangled with other seaweeds in coral or reef flats, in tide pools or subtidal habitats, it can also be carried in bulk by waves to beaches. When fragments of *Lyngbya* lodge inside a person's bathing suit, they can cause minimal to severe inflammation of the skin, depending on the person's allergic reaction. Anyone exposed to this alga should wash the affected area immediately with soap and water, and change the bathing suit.

While the blue-green algae mentioned above are a nuisance, one very much in the news nowadays is *Spirulina*, because of its food value. There are over 35 different types, originally isolated from salt lakes in Africa, South America and Mexico. It has been eaten in Chad and Mexico for centuries.

Dried *Spirulina* has 65 to 70% protein, 12.4% carbohydrates and 7.3% fats, the protein content being twice that of soyabean. It has 600 calories per 100 grams dry weight, and contains vitamins A, B_1, B_2, B_6, B_{12}, C and E. It is non-toxic, and easy to digest and absorb. However, it is not a complete protein source, since it is low in methionine and several other aminoacids.

Fig.15 ***Ulva*** ***Enteromorpha***

The green algae, so called because of their colour, may vary from microscopic single- celled motile (moving by means of whip-like flagella) forms, coccoid forms like *Pyramimonas*, or non-motile single-celled dendroid (tree-like) *Prasinocladus* to larger forms visible to the naked eye. Their shapes vary a great deal so that we have thalloid (*Ulva*), siphonous or tubular (*Enteromorpha*), feathery (*Bryopsis*), fan-shaped (*Udotea*), penicillate (*Penicillus*), brush-like (*Chamaedoris*), umbrella-like (*Acetabularia*), club-shaped (*Bornetella*), grape-like (*Boergesenia*), cactus-like (*Halimeda*), vermiform or worm-like (*Neomeris*), fintail-shaped (*Abrainvillea*), honeycombed (*Dictyosphaeria*), net-like (*Microdictyon*) or with runners (*Caulerpa*).

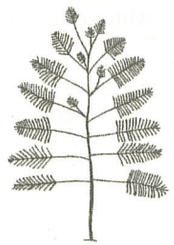


Fig.16 ***Bryposis***

Among the green algae, a whole family, Dasycladaceae incorporate calcium carbonate in their body as an encrustation. Of 55 genera, ten are still living, the rest having become extinct and known only as fossils.

Unlike the blue-green algae which have no mode of sexual reproduction, the green algae reproduce vegetatively as well as sexually. In asexual reproduction, a cell divides to form a few flagellated single-celled zoospores which swim away and soon settle down to form a new seaweed. The zoospores mostly have four flagella. In sexual reproduction also, there are flagellated single-celled gametes (sex cells), but two gametes have to come together and fuse with one another to form a zygote, which then

forms the new alga. The gametes usually have two flagella.

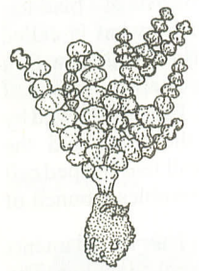


Fig.17 ***Halimeda***

In many seaweeds such as the sea lettuce (*Ulva*), a plant forms only zoospores, which form a new plant. This, in turn, produces only gametes, which also form a new plant. Thus there is what we call an alternation of generations. Both the plants the ones that form zoospores and those which produce gametes, look alike and cannot be distinguished; the alternation of generations is called isomorphic. In *Ulva*, both the fusing gametes look alike, but in others such as *Enteromorpha*, there is a larger female gamete and a smaller male gamete. Even the plants formed from zoospores and those from gametes in *Enteromorpha* look different. In the male plants, the parts where the gamates are formed are orange-yellow, while those in the female plant are yellowish-green.

Let us look at a few of the green algae. In *Ulothrix*, of which most of the 30 species live in fresh water but there are a few marine forms, the weed is filamentous, being made up of rectangular cells, each with a circular band of chloroplast. The filament is attached to a stone by an end cell, often lacking a chloroplast, modified as a holdfast. *Ulothrix* breeds vegetatively either by the breaking up of a filament which floats away, or by giving out zoospores with four flagella. Sexual reproduction is by two gametes, each with two flagella, fusing to form a zygote, which then grows into a new plant.

Enteromorpha also has a thallus which is two-cell thick, but the two layers separate from one another to form a tube of about 12 mm diameter, looking somewhat like our intestine hence the name. It prefers places in the intertidal zone where there is admixture of fresh water. It, too, has an alternation of generations, but the gametes are of different sizes, and the tips of the plants that produce them are differently coloured, as we saw earlier. *Enteromorpha* is eaten in Japan and China.

Fig.18 ***Cladophora***

Cladophora is a filamentous seaweed, many species of which are also found in fresh water. Cells joined end to end form the filament, but the cell walls have three layers: an outer, hard, chitinous layer, a middle layer containing pectic compounds, and an inner layer of cellulose. The dark green filaments are branched to give a feathery appearance, forming tufts some 12 cm high, attached to a stone by short branches called rhizoids. There is an alternation of generations.

In all the green seaweeds described so far, the cells are separated by cross-walls or septa (partitions). But in *Bryopsis*, the whole thallus is formed of one vast cell, without septa, and containing many nuclei. Such a structure is called a coenocyte. This seaweed has a portion creeping over a stone, throwing out vertical filaments at intervals. These filaments branch and re-branch to form a feathery structure some 10 cm high. The secondary branches are called pinnules. The inside of *Bryopsis* is a continuous coenocyte containing small disc-like chloroplasts and nuclei, without any septa. However, older pinnules develop septa across their bases and drop off to form new plants by sexual reproduction. The broken-off pinnules form structures, called gametangia, which contain the gametes. The male gametes are small and have yellowish chloroplasts, while the female gametes are three times larger and have a green chloroplast. Male and female gametes are formed in different plants. The male plant has those pinnules containing male gametes yellowish, while the female plant has dark green fertile pinnules.

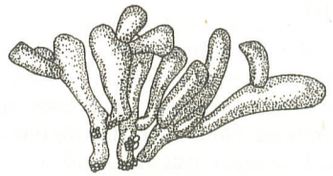


Fig.19 ***Valonia***

Valonia is found in tropical seas. There are about 18 species. The young plant consists of a bladder-like cell with many nuclei formed by what is called segregative cell division. The division begins with a differentiation of a dense lens-shaped mass of protoplasm at a local area in the cell. This is followed by a formation of a wall between the mass and the remainder of the protoplasm. The small lens-shaped cell thus differentiated then elongates into a holdfast cell. Ultimately it resembles a bunch of grapes.

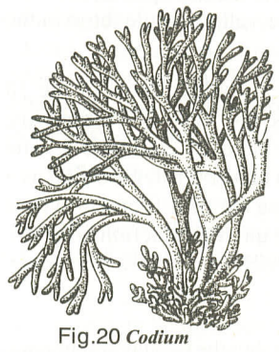


Fig.20 ***Codium***

Dead men's fingers (*Codium*) has its filaments woven together to form a large, much-branched thallus. The branches are about the thickness of a pencil and are covered with velvety hairs. The filaments have swollen, elongated vesicles, called utricles, which project all round the thalli and contain chloroplasts. Each utricle bears two gametangia. A male gametangium produces a few thousand small, biflagellate male gametes. Female gametangia produce fewer (a few hundred) but larger gametes. The thallus in *Codium* is a coenocyte. *Codium* is a favourite food of the nudibranch *Elysia viridis*.

Members of the family Dasycladaceae have branched thalli encrusted with calcium carbonate, so that they have left a fossil record, of about 45 genera, right from Ordovician times some 400 million years ago and reaching their greatest development in the Triassic and Jurassic periods. Some 10 genera still exist.

The mermaid's wine glass (*Acetabularia*) is a member of this vast family. Growing in tropical and sub-tropical seas, it varies in size from 5 mm to 10 cm, the top of the mushroom-shaped thallus being up to 12 mm. The thallus has a holdfast of branched root-like rhizoids. The vertical part has a ring of fine hair-like branches at its tip. As it grows, another ring of hairs is formed higher up, while the original (lower) hairs are shed, leaving a circular scar on the axis of the thallus. Rings of hairs are thus formed, and shed, as the plant grows, until the growth ceases. At the top is the remaining ring of branches, which may be free or may be fused to form a flat plate, giving the plant its mushroom-like appearance.

In the middle of this ring, on the upper side, is another ring of branches whose tips bear fine hairs forming a "corona superior". In some species, there is also a corona inferior on the underside. Gametangia are formed in this middle disc. Their contents divide into many thick-walled cysts. The cysts, set free in the water, remain dormant for some time, but their contents divide into a large number of biflagellate gametes. In spring, the cyst bursts and pairs of gametes fuse to grow into a new plant.

For most of its life, *Acetabularia* has only one nucleus in its coenocyte, situated at the base of the axis and growing to twenty times its original size. As the fertile disc at the top of the plant appears, the nucleus divides many times, and the resulting numerous nuclei are carried by streaming movements of the cytoplasm to the gametangia.

Apart from three fresh water genera, all the brown algae are marine, found in the higher intertidal and upper littoral zones. None are single-celled and none are colonial. Most live in cooler seas, and many yield commercial products such as algin, iodine, soda and potash. Their shapes vary from filamentous (as in *Ectocarpus*), thallose (*Punctaria*),

Fig.21 ***Padina***

fan-shaped (*Padina* or mermaid's fan) saccose or bladder-like (*Adenocystis*), tubular (*Scytosiphon*, *Coilodesme*) and palm-like (*Postelsia*). Brown seaweeds have the green chlorophyll in their bodies (such as chlorophylls *a* and *e*, several xanthophylls and beta carotene, but they get their brown colouration from the pigment fucoxanthin. Their reproduction shows alternation of generations, but is more complicated in that there are short cuts but only for one generation from vegetative to vegetative and sexual to sexual.

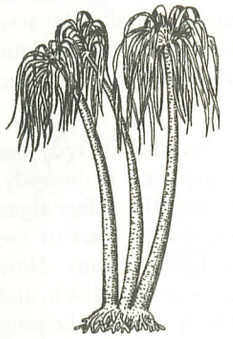


Fig.22 ***Postelsia***

Well known among the brown seaweeds are the giant kelps. *Macrocystis* found in the eastern Pacific Ocean, grows to 30 metres. Each long-branched stipe (stem) has a flattened leaf-like blade (lamina), at the base of which is a gas bladder which helps it to float. *Nereocystis*, also of the Pacific Ocean, is slightly less longer at 24 m for the stipe. Above the gas bladder at the upper end of the stipe are short branches, each having a 3-metre long blade.

Kelps do not grow at their tips. They have a region of growth at the base of the blade where it joins the stipe, so that it lengthens the blade above it as well as the stipe below it. They have an alternation of generations, but it is the vegetative sporophyte which we see as a plant; the reproductive gametophytes are microscopic.

Fig.23 ***Fucus***

Just like the giant kelps, even the common *Laminaria* of temperate seas is absent in India, only a few wracks (*Fucus*) being found here. The thallus of *Fucus* has a single outer layer of rectangular cells rich in chloroplasts. This layer is called the meristoderm. Below it is the cortex, having rounded cells with fewer chloroplasts. In the centre is the medulla having long filaments covered with a gummy mucilage. The filaments are thin- as well as thick-walled, the latter especially abundant at the mid-rib. The medulla has very few chloroplasts, and it serves to support the thallus and transfer the food. There is no alternation of generations in *Fucus*, the fertilised egg developing directly into a gametophyte (sexually derived plant).

Fig.24 ***Sargassum***

The most well-known brown alga is the gulfweed (*Sargassum*), also occurring in Indian seas. It is the only seaweed found in the open ocean well away from the shore. Some 230 species are known.

To begin with, *Sargassum* is attached by a holdfast to the sea bottom in tropical seas. It has a superficial resemblance to higher plants, having "leafy" extensions and branches looking like "stems". The short axis has a tuft of rather broad basal "leaves". The long, branching secondary shoots have leaves of different sizes. Interspersed are stalked bladders filled with air, called vesicles and special fruiting branches. It is the bladders which give it its other name grape-weed; from the Portuguese word "sarga" for grapes is derived its scientific name *Sargassum*.

Breaking loose due to wave action or currents, the seaweed continues to live and grow vegetatively, elongating and forming

new branches. Pieces torm loose from Florida and Central America drift in the Gulf Stream and are carried by the current eddy to gather in a huge patch, some 4 x 10^6 square kilometres in the windless Sargasso Sea. Here the weed shelters a special community of animals and fish, many of which are found nowhere else in the oceans. The weed continues to flourish but, as it grows, the number of bladders decreases, so that it gradually sinks below the sunlit upper layer of the sea and ultimately dies.

Sargassum bacciferum, first seen by Columbus and later described by Humboldt, led to a mutiny by his sailors in 1492. As seaweeds normally grow in shallow seas, they were worried that the ships would run aground on some hidden undersea rocks and sink. As the sailing ships had been becalmed for days together in the Sargasso Sea with no wind or current, they also believed that the huge mass of gulf-weed held the ships fast, preventing them from forging ahead and that they would die of starvation and thirst.

Red algae derive their pigments from two colours, phycoerythrin-r (red) and phycocyanin-r (blue). Depending on the proportion of these two pigments in the body, they may appear from bright red to blue. They can live in depths greater than other algae can because of these pigments. As light passes through water, the red part of the spectrum is absorbed first, and at middle depths only green light remains. Now chlorophyll does not absorb much green light. However, phycoerythrin absorbs it, and passes on some of the energy which it absorbs to the chlorophyll, thereby helping photosynthesis.

Fig.25 ***Porphyra***

A great majority of red algae are marine. Like the blue-green algae, they have no flagellated cells; even the male reproductive gametes lack flagella, being carried about by water currents. They vary in shape from thread-like (as in *Polysiphonia*), thallose (*Porphyra, Halymenia*), feathery (*Asparagopsis*) to bladder-like (*Halosaccion*), beaded (*Scinaia*) or leafy with mid-rib (*Laingia, Phycodrys*).

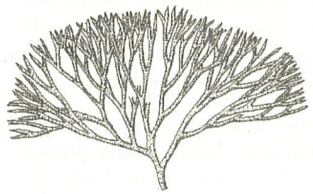


Fig.26 ***Scinaia***

Red algae reproduce both vegetatively and sexually. In the former, instead of the motile flagellated zoospores of green and brown algae, there are tetraspores. Sexual reproduction is very complicated. The male gamete, called spermatium, fuses with the egg inside the flask-shaped organ called carpogonium. The fertilised egg grows into two types of asexual spores called carpospores and tetraspores. The different types of plants resulting from the two kinds of reproduction are called carposporophytes, tetrasporophytes and gametophytes. The tetrasporophyte is usually similar to the gametophyte, but the carposporophyte is completely different and is parasitic on the gametophyte.

Red algae are divided into two subclasses. The more primitive Bangioideae have a few single-celled forms, others where the single cells are joined by mucilage to form a filament, and yet others truly filamentous or parenchymatous. The purple laver (*Porphyra*) falls in the last group.

The thallus in the other, larger subclass Florideae are basically filamentous, but owing to the complex branching and binding together, they appear like a sheet, an

example of pseudoparenchymatous thalli. The Florideae are divided into six orders, viz. Nemalionales, Gelidionales, Cryptonemiales, Gigartiniales, Rhodymeniales and Ceramiales.

The Nemalionales (e.g. *Nemalion*) are purplish mucilaginous algae growing to a height of 7.5 to 25 cm from a small holdfast to form a branched thallus. The mature thallus has a colourless centre made of closely woven filaments of elongated cells, and an outer cortex of short, branched filaments ending in hairs.

Fig.27 ***Gelidium***

Gelidium, of the Gelidionales, is commercially important as the source of agar. It has translucent, horny, crimson to purple, branched, flat or cylindrical thalli.

The Cryptonemiales are a large order, with 85 genera and 650 species. It includes the family Corallinaceae, which have their thalli hard and brittle due to deposition of lime and magnesia. They were earlier classified with corals; only in the mid-nineteenth century was their true nature known. They appear pink due to the overlapping of red chloroplasts and white lime. They play a great role in reef building. In fact, it is these coralline algae which are mainly responsible for the formation and growth of many so-called 'coral' islands and 'coral' reefs. *Lithothamnion* and *Lithophyllum* are flat and crustose, but *Bossiella* has cylindrical branched and jointed forms. Coralline algae have contributed largely to the formation of the earth's crust, and have been known from very early periods. *Lithothamnium jurassicum* is found in Jurassic strata. These were so numerous in Tertiary times that entire mountains are built up from their remains. Of 276 species of coralline algae, 82 occur in the tropics, 182 are found in temperate seas and 12 in the arctic or sub-arctic regions.

Chondrus, popularly called Irish or carragheen moss, falls in the Gigartiniales. It is used as food, in making jellies and blancmange in Ireland, and was earlier used as a medicine for cough. *Gigartinia*, which has a similar appearance to *Chondrus*, can be distinguished by its dark colour. Some 90 species occur, and they too yield agar. *Gracilaria* is yet another genus in this order, which yields agar.

The dulse (*Rhodymenia*), belonging to the order Rhodymeniales, is also edible, eaten fresh as salads, and is thought to be excellent to overcome the effects of seasickness. The thallus is often hollow, as the axial filament lies inside a hollow cylinder instead of a solid one.

Polysiphonia belongs to the order Ceramiales, which has some 160 genera containing 900 species. The thalli are branched filaments, so formed that the central filament is surrounded by a number of longitudinally arranged filaments or "siphons".

4 The Living Bridge

Continuous as the stars that shine
And twinkle on the Milky Way,
They stretch in never-ending line
Along the margin of a bay:
Ten thousand saw I at a glance,
Tossing their heads in sprightly dance.
The waves beside them danced, but they
Outdid the sparkling waves in glee.
A poet could not but be gay
In such a jocund company:
I gazed and gazed but little thought
What wealth the show to me had brought.

William Wordsworth

People usually distinguish plants and animals by the former having green chlorophyll (the photosynthetic pigments in the leaves) and lack of mobility, while animals lack chlorophyll and can move about. In the sea (and also in fresh water) we have what may be called borderline cases, exemplified by the Dinophyceae (the name given by botanists) or Dinoflagellata (the name given by zoologists). Botanists include them in the plants as they (or at least most of them) use the sun's energy to make food from water, carbon dioxide and minerals, and are encased in a skin of cellulose, the same substance that is found in land plants.

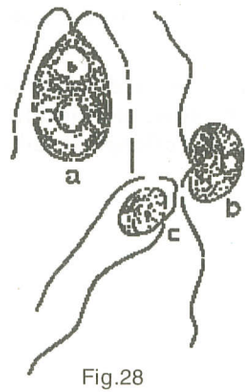


Fig.28

Dinoflagellates: (a) *Dunalliela* (After Hamburger), (b) and (c) *Nephroselmis* (After Parke Rayns)

Typically the dinoflagellates have two whip-like flagella (long, hair-like organs) lashing in the water one in a longitudinal groove, called sulcus, trailing behind the organism, to push it forward, and another in a transverse groove, called girdle, running equatorially like a belt around the waist, whose lashing gives the organism a spinning motion. Because of the swimming mode of locomotion, and as some of them capture food with their flagella, zoologists call them animals.

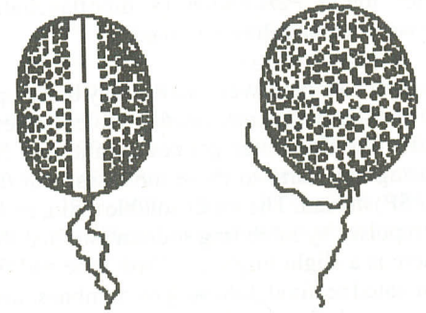


Fig.29 ***Exuviaella*** **(After Schutt)**

In other forms, such as *Exuviaella*, there is no transverse groove; the cell wall, when present, is divided vertically into two halves or valves. The two flagella are situated at one end of the cell.

Dinoflagellates have a red eye-spot to detect light, and indulge in daily up-and-down migrations of over 45 metres, at speeds of 0.05 to 3 cm per minute, a journey two million times their own length, or equivalent to a man diving 3,200 kilometres.

Their body may bear spines or frills whose friction reduces their tendency to sink; some also have an oil globule serving the same purpose.

The Peridiniales have a cellulose cell-wall, called theca, made up of transparent, perforated plates. The Gymnodiniales have no plates but are enclosed in a thin, structureless pellicle (cell-wall).

When favourable physical and chemical conditions exist, dinoflagellates multiply in such vast numbers that they form concentrated floating masses called "blooms". The water may be discoloured red, brown or green, depending on the colour of the chloroplasts (photosynthetic pigments) in the organisms. There may be 90 million cells in a litre of sea water, and the phenomenon is called "red tide". Dinoflagellates encyst when conditions are poor for growth, and a large seed population of cysts is believed to exist in offshore bottom-surface sediments. The resuspension, encystment and growth of dinoflagellates are the red tide blooms. Red tides result in mass mortality of fishes and other marine animals, when thousands of dead fish cover the sea surface or get washed up on the shore.

The first "red tide" is recorded in Exodus 7:21 of the Bible as: All that were in the river turned to blood. And the fish that was in the river died, and the river stank, and the Egyptians could not drink of the water of the river.

In 1835, Charles Darwin on H.M.S. *Beagle* saw such a bloom off Chile. He wrote: "One day (we) passed through great bands of muddy water, exactly like that of a swollen river. Some of the water when placed in a glass was of a pale reddish tint, and examined under the microscope was seen to swarm with minute animalculae darting about and often exploding."

In 1858, Carter found *Peridinium* (a dinoflagellate) responsible for the discolouration of sea water around Bombay island.

When blooms occur near land, wave action may break up the dinoflagellates and the inshore wind blows their fragments, causing violent sneezing and coughing. The toxins (poisons) of the dinoflagellates get concentrated in filter-feeding clams and mussels without causing any harm to these molluscs. But they can cause paralytic shellfish poisoning (PSP) in man. The water soluble toxin, called saxitoxin, blocks the generation of nerve impulses by inhibiting sodium ion flux, thus affecting nerves and skeletal muscles. There is a slight tingling of lips, face and fingertips within half an hour of eating contaminated seafood, followed by numbness and paralysis of limbs and neck. Breathing becomes difficult, and death may occur in 2 to 24 hours. The dinoflagellate *Gonyaulax* causes PSP, and there is no cure.

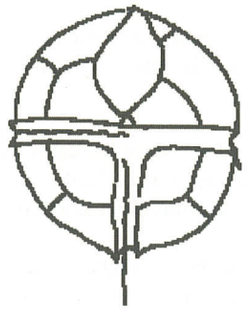


Fig.30 ***Gonyaulax***

A milder illness, neurotoxic shellfish poisoning (NSP) is caused by the fat-soluble toxin, brevitoxin, of *Ptychodiscus* which accumulates in oysters. It is not fatal, but the tingling sensation is followed by a state of confusion and voluntary muscle incoordination, slowing of rate of heartbeat and diarrhoea. These symptoms are caused by too large an influx of sodium ions depolarising nerve and muscle cells.

Fig.31 ***Ptychodiscus*** **(formerly *Gymnodimium*) (After Lebour)**

Other toxins of *Dinophysis* cause diarrhoetic shellfish poisoning (DSP), resulting in vomiting and diarrhoea. The dinoflagellates *Peridinium, Glenodinium, Gonyaulax, Ptychodiscus* (formerly *Gymnodinium*) and others are implicated in red tides and mass fish kills.

Many marine dinoflagellates exhibit bioluminescence, i.e., they emit light. The most famous is *Noctiluca*, which feeds on fish eggs. Some places well known for being permanently phosphorescent are Bahia Forforescente in Puerto Rico and Falmouth harbour in Jamaica. Other dinoflagellates, such as *Oodinium* and *Paradinium* are parasites on fish and zooplankton organisms. The number of cells may be as many as three million in a litre of sea water. *Noctiluca* is quite large, being 1 mm. Yet others live inside corals as symbionts; they retain their chloroplasts (the packets containing chlorophyll) but lose their flagella, as locomotion is no longer necessary inside the corals. They are known as zooxanthellae.

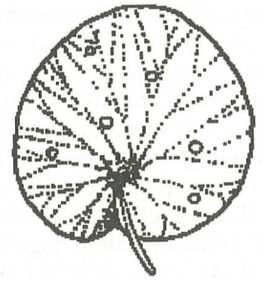


Fig.32 ***Noctiluca*** **(After Pratje)**

The common pigments inside Dinophyceae are chlorophyll *a*, chlorophyll *e*, beta-carotene and a number of xanthophylls. Some of the xanthophylls are found only in Dinophyceae and nowhere else. The pigmentation is usually that found in diatoms and brown seaweeds. In those dinoflagellates that feed like animals by catching live prey, chloroplasts are absent. Some such forms are parasitic on fish and copepods.

Dinophyceae reproduce by cell division, each cell simply splitting into two. Each daughter cell gets half of the parent's theca and grows the other half. But in some forms, the theca breaks open, the living cell comes out and divides into two; here both the daughter cells have to make their own theca.

While the dinoflagellates have two flagella, there is another group, comprising organisms called slipper animalcules or *Euglena*, and found in fresh water as well as in the sea. Many of them have chloroplasts containing chlorophyll, and most have a flagellum for locomotion. This again gives rise to a debate whether they are plants or animals. It is known that life evolved from some primeval living matter some thousand million years ago, and from this common stock which used to be known as the Protista the two main kingdoms, viz. plants and animals, branched out later. Botanists place *Euglena* in the Euglenophyta, while zoologists place it in Protozoa.

Euglena typically has a spindle-shaped body enclosed in a pellicle (skin or cell-wall). At the blunt front end there is a funnel-like gullet ending in an enlarged reservoir and housing a whip-like flagellum.

Fig.33 *Euglena*

Some species of *Euglena* are colourless, as they have no chlorophyll. Their nutrition is entirely of the animal type, as they feed on small organisms. Others have strap-shaped chloroplasts radiating outward, like the arms of a starfish, from a central point. These manufacture and store starch-like grains of a carbohydrate called paramylum, shaped like discs, rods or rings and useful in identifying the species. Other Euglenas appear red in bright sunlight, and green in cloudy weather. This is because their body has many granules of a red pigment called haematochrome. Under a bright sun, they are dispersed evenly throughout the cell, so that the *Euglena* appears red. But in cloudy weather these red granules clump together in the centre of the cell, unmasking the green chloroplasts arranged round the circumference, so that the *Euglena* now appears green. Some kinds of *Euglena*, when kept in the dark, lose their chlorophyll, and then get their nourishment by absorbing organic matter from the water. This mode of feeding is called saprophytic by botanists and seprozoic by zoologists.

Many Euglenas live inside the body of animals such as flatworms, earthworms, copepods, rotifers (wheel animalcules), eelworms and amphibians. Some, like the marine *Colacium*, live together as a colony of individuals. They have no flagella, and are attached at their hind ends to branched sticky stalks.

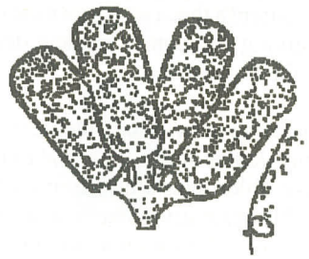


Fig.34 *Colacium* (After Stein)

Euglenas reproduce by cell division, the split starting at the front end and progressing backward until there are two daughter cells. In some cases, the cell gets enclosed within a cyst and divides several times, after which the cyst bursts and many daughter cells emerge.

5 The Tree That Makes Land

Fig.35 **Distribution of mangroves in the world**

When Columbus discovered the New World, he was intrigued by the sight of trees growing so thickly in shallow sea water that (he wrote) "a cat milgh not get ashore". The trees were red mangroves. Mangroves are plants that can live in loose, saturated, salty soils; they are submerged at high tides but exposed at low tides. They are not seaweeds, but are highly evolved plants that bear flowers. They are marine plants capable of living, growing and reproducing without the help of "land" or rain. But they grow best in brackish water near the mouths of rivers and creeks, and can sometimes be found in virtually fresh water. In the laboratory some can live and grow for years in water that can be drunk. India has 28 species of mangroves out of 60 kinds in the world.

The best known mangroves are the red mangroves (*Rhizophora*) and black mangroves (*Avicennia*), and even a novice can distinguish between the two. Red mangroves have prop roots (stilt roots) looking like the legs of giant spiders wading in shallow water. Black mangroves have pneumatophores or breathing roots sticking vertically out of the mud into the air. These have tiny pores which take in air to supply oxygen to the underground roots, which would otherwise suffocate in the poorly aerated mud.

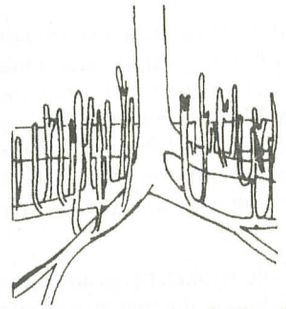


Fig.36 **Breathing roots of *Avicennia***

Red mangroves and the related *Bruguiera* are viviparous, i.e., they germinate while still attached to the parent tree. The seed germinates within the 2.5 cm long, brown, conical fruit, and about three weeks later the sprout (seedling) begins to emerge from the tip of the fruit. Growing for 9 to 10 months, each fruit sends out a long slender, spike-like primary root that, depending on the species, may reach a length of 50 to 100 cm while still hanging from the tree. It looks like a green wooden dart. When it detaches and falls, at low tide it will stick into the mud, send out roots and soon become anchored to the spot. But most seedlings float away with the tide.

Fig.37 **Stilt roots of mangroves**

The seed may drift for hundreds of kilometres, remaining alive for a year or more, even producing secondary roots while afloat. At first they float in a horizontal position, but as they grow they tilt more and more to the vertical. After a month most are floating vertically. They may live a year or longer while totally submerged. The saltier the water, the longer the seedlings will float. But, if the seedling hits branches as it falls, landing upside down, or if it falls on dry sand in bright sun, or drifts to unsuitable shores, it will perish.

Fig.38 **Hanging seed of mangrove**

A healthy red mangrove will produce more than 300 seedlings in a year. On a walk at low tide, hundreds of such seedlings can be seen to be dead and rotting. About a hundred may have recently rooted, each giving out a pair of leaves. And there will be thousands more which have recently fallen and should grow if the tide shifted them to an erect position.

About half the seedlings produced will be washed away to new locations. Pushing them upright in mud will produce rootlets in a week. Once a seedling gets anchored, it grows quickly being 60 cm high in the first year. In the second year it sends out stilt roots which extend outward from the trunk in wider and wider circles. After three to four years it is anchored so firmly that it can withstand storms. Aerial roots also grow down from the branches and form secondary trunks with their own stilt roots. Stilt roots are highly developed in *Rhizophora mucronata* and *Acanthus ilicifolia*, extending up the trunk to 75 cm or more, but less so in *Rhizophora conjugata*. In *Bruguiera*, the horizontal parent roots bend out of the mud into knee-like structures.

Other mangroves *Avicennia, Sonneretia, Ceriops*, etc. have a different root system, where the underground roots give out branches which then grow vertically out of the mud to project upward for 10 cm (in *Avicennia*) but as much as 50 cm (in *Sonneretia*).

Corals and mangroves require very different conditions for survival and growth. The former need clean, sediment-free, undiluted, constantly moving warm water, while the latter flourish in still, protected, sediment-laden water. Yet we often find corals and mangroves in the same areas, as in the Andaman Islands. Mangrove seedlings must have protection from surface currents; on exposed sand beds and mud flats they would be swept away. But if protected by a coral reef which breaks the force of the waves, mangroves will take root. As the corals continue to grow outward towards the sea, mangroves grow along the rubble-strewn inner edge.

As the mangroves flourish, they trap more and more silt. Broken twigs and roots decay to form mangrove peat, enriching the soil. Birds roosting in the mangroves add guano (faeces), further enrich the soil. As the sediment accumulates and builds up, other mangroves and mangrove-associates establish themselves, forming different zones. On the seaward side are *Rhizophora*, followed by *Kandelia, Ceriops*, and then *Bruguiera, Avicennia, Lumnitzera* and *Sonneretia* (white mangrove). Associated with the true mangroves are the saline palms *Nepa fructicans* and *Phoenix paludosa*, the fern *Acrostichum aureum*, the sea holly *Acanthus ilicifolia*, the looking-glass plant *Heritiera litoralis* and *Heliotropium ovalifolium*. As the force of the waves is broken by the mangroves, silt builds up and land is created from the sea. As the ground level rises, the mangroves are replaced by shore plants such as *Aegiceras* and *Excoecaria*. These are followed by salt-tolerant grasses like *Myriostachya, Oryza sativa* var. *patnai* and *achra, Oryza coarctata* (wild rice) and coconut palms. As the mangroves thrive, instead of the low bushes with twisted trunks we have red mangroves as high as 24 m, as in the Sunderbans, which are even a haunt of tigers. Observed from the sea, these mature mangrove forests look like a solid green wall. But as we approach closer, twisting channels of water can be seen between the islands, sometimes as tunnels framed by branches merging overhead to form a canopy. But the soft, squelchy mud where we may

sink up to the knees, the warm and sultry air, the smell of muck and the swarms of mosquitos deter any but the most determined person to set foot and venture to go in.

Mangroves have their uses. Their thick bark is used for tanning leather. The hardwood is used for making furniture. Their wood is used for fuel and the leaves for camel and cattle fodder. But the most important "use" is their value in stabilising and preserving the coastline, especially against storm surges. Wherever mangroves have been destroyed, humankind pays the price in increased coastal erosion. Mangroves form a cheaper and good-looking bulwark against erosion of land than the costly and ugly tetrapods.

> Others, that like the broad banana growing,
> Raise their long wrinkled leaves of purple hue
> Like streamers wide outflowing;
> Trees of the deep, and shrubs, and fruits and flowers
> As fair as ours,
> Wherewith the Sea-nymphs love their hair to braid.

By no stretch of imagination can I be called a botanist. Yet there is a plant – albeit a small shrub – named after me. It came about like this. I was leading a party of nature-lovers going to Lakshadweep. One of my assistants was MRA, a noted botanist. At Kalpeni, one of the islands on our itinerary, we climbed to the top of the lighthouse from where we had a panoramic view of the island. MRA did not come up with us; he was more interested in collecting leaves and flowers from the local flora for a herbarium. From the lighthouse top we could see him a tiny figure plucking away at the plants and putting them away carefully in his haversack.

I had a colleague who kept us laughing with his pranks and witty remarks. On seeing MRA down below, he told me, "you are a useless leader. You do not see to our comforts or feed us well. See MRA down there; he must be desperately hungry to collect leaves for today's lunch. He is wandering about like a hungry cow which is left by its heartless owner to roam on the streets and find food from garbage cans to fill its belly and thus fend for itself". I kept my counsel then, but I had the last laugh when, a few months later, I read about the discovery of a new subspecies of plant found at Lakshadweep, and named *Sida acuta* var. *chhapgarii*. I had been immortalised!

Mangroves flourish in the intertidal region and are exposed at low tides. They are, of course, flowering trees. There are other marine and brackish water plants which do not grow as tall as trees, but are mere herbs. Text-books often mention the popular turtle grass (*Thalassia*) and eelgrass (*Zostera*). Along with others like *Amphibolus, Posidonia, Syringodium,* etc., they do not occur in our seas, although our Indian *Diplanthera uninervis* was named *Zostera uninervis* by Forskal.

In India we have *Cymodoecea, Enhalus, Halophila, Ruppia* and *Zanichellia. Cymodocea* are submerged marine herbs with slender, rigid, jointed, creeping rootstocks. These are perennial, but their leaves drop off annually, leaving scars. The common Indian species are *C. ispatifolia*, *C. rotundata* and *C. serrulata*.

Diplanthera uninervis is also a submerged marine herb with slender, rigid, jointed, branching rootstocks bearing, like *Cymodocea*, the annual scars of fallen leaves. Its leaves are narrowly linear, 3-nerved, with 2 minute lateral teeth.

Enhalus acorides grows together in large clumps along shallow shelter of coasts forming dense submerged vegetation. The long (60-90 cm), narrow (1-2 cm) leaves are

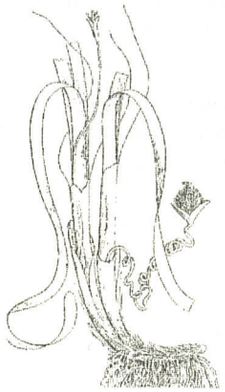


Fig.39
***Enhalus acroides* plant**

usually coated with mud and may also have a growth of the brown alga *Ectocarpus*. Flowers and fruits are borne from September to November. The fruits hang in the sea water, covered by many stiff bristles. As the fruit bursts open, the few large seeds nestling loosely in the inner, soft fleshy tissue are exposed to sea water. Many air-filled cavities in the seed's outer coat prevent the seed from sinking. But this layer soon comes off, remaining attached to the seed as a loose cap. The developed seed now sinks in the sea water to grow as a new plant. A fibre from this plant is used for making fishing nets.

Often associated with the aforestated plant is *Halophila ovalis*, a slender, creeping herb growing in sheltered, sandy bottoms in the sea as well as in brackish waters, and often growing gregariously on coral reefs. It has long (7·5 cm) but narrow (1 cm) leaves, and the plant is often almost buried in the muddy bottom. It flowers in September and October. It is used as a manure in coconut plantations.

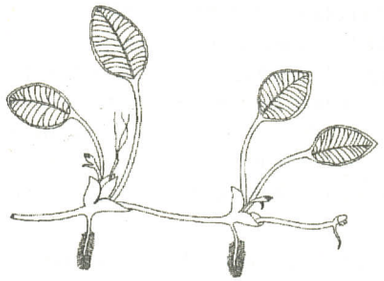


Fig.40 ***Halophila ovalis***

Rupia maritima is a slender, branched herb growing submerged in brackish water. The creeping rootstock gives rise to tangled masses of flaccid stems and branches bearing filiform leaves having a broad sheathing base and tapering apex. The leaves are alternate or subopposite. The minute, hermaphrodite flowers and fruits are seen from January to May.

Fig.41
Zannichellia ***Ruppia***

Zanichellia palustris pedicellata are a highly variable species of submerged perennial herbs growing in salt marshes, brackish and sometimes even fresh water lagoons. The rootstock is slender, with slender leafy stems. The minute flowers and fruits are seen from February to June.

6 The Itsy-bitsy, Teeny-weeny Drifters of the Sea

Transparent forms, too fine for mortal sight,
Their fluid bodies half dissolved in light.

In 1845, when Johannes Muller poured sea water through a fine-meshed net, he was amazed to see myriads of animals retained in the meshes. He refined this technique by towing a conical net from a boat, and was so thrilled that he entreated his contemporary, Ernest Haeckel to try it, saying that once Haeckel had glimpsed this world of drifting life, he would never be able to leave it.

Fig.42 **Plankton net**

Some animals in the sea, such as fishes, squid, turtles, dolphins and whales are strong enough to swim against currents. They are grouped as "nekton". Others can swim, but so feebly that they cannot overcome the effect of currents and tides and drift with the sea water; these constitute the plankton. Drifting plants in the plankton are called phytoplankton, while animals comprise the zooplankton.

Some zooplankters spend their entire life drifting in the sea; they are permanent plankton or holoplankton. Many other animals that live on the sea bottom as adults (such as worms, barnacles, lobsters, crabs, molluscs and echinoderms) or are powerful swimmers (fishes) have larval stages (young) as drifters; these are the meroplankton.

Most of the plankters in the sea are feeble because they are small. This is typified by the copepods crustaceans invariably present in almost all plankton hauls and the most numerous components of zooplankton. There may be as many as 1,07,140 copepods in a cubic metre. Ranging in size from a couple of millimetres to a centimetre, most are about the size of a grain of rice. By vibrating their antennae at some sixty strokes a second, they create a current to sweep minute one-celled plants and bacteria to a food-chamber between their mouth-parts which act as fine filters. A single copepod may consume 120,000 diatoms in a day. They are, therefore, called the grazers or sheep of the sea. They are, in turn, fed upon by fish such as herring.

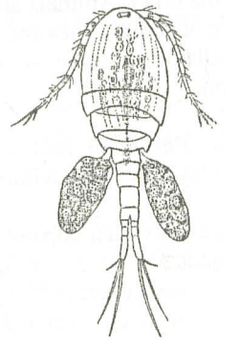


Fig.43 **Copepod**

As there are no hiding places in the open sea, many zooplankters seek protection by being transparent. Such are the medusae (jellyfish), comb-jellies (ctenophores) and salps. A jellyfish has an umbrella- or bell-shaped body with many tentacles around its rim and a mouth hanging down from the centre. They move by a gentle jet propulsion caused by rhythmic contractions of the bell and catch their prey by paralysing it with their stinging cells. They range in diameter from a few millimetres to half a metre, although a giant in the Arctic seas is two metres wide with 35-metre long tentacles. Their body is 95 per cent water, which prevents them from sinking in the sea.

Fig.44 **Jellyfish**

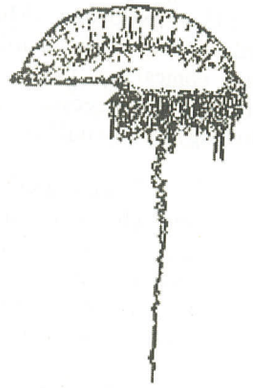


Fig.45 **Portuguese man- of- war**

Allied to jellyfish is the Portuguese man-of-war (*Physalia*) which drifts on the sea surface with its gas-filled float and with its long tentacles hanging down to sting and catch its prey (see the Chapter "Borne on the Purple Wind").

The equally transparent comb-jellies or sea-gooseberries swim by beating their tiny hair-like cilia arranged in eight bands. Two long tentacles have a sticky coating to help trap prey– fish fry, copepods, etc. Venus's girdle (*Cestum*), also a ctenophore, is aptly named from the flat, ribbon-like body which may be 1.5 metres long but only a few centimetres wide. Though equipped with eight rows of cilia, it swims gracefully by rolling and unrolling its ends.

Salps are related to sea-squirts. The individual animal looks like a transparent, 3 cm long barrel open at both ends, with muscular bands like barrel hoops which pump water in at one end and out at the other. Animals are often joined together to form 6-metre long chains. The presence of comb-jellies and salps is an indication to fishermen that pomfrets are nearby; they call this gelatinous soupy water as "pomfret water". Salps also herald the presence of herring.

An amphipod crustacean, *Phronima*, hollows out the body of a salp and lives inside the barrel-like home, even laying its eggs within.

Pyrosoma looks like a huge individual salp but is actually a colony of hundreds of salp-like forms, a hollow cylinder almost 2.5 m long and 30 cm in diameter. The individual animals are on the cylinder's outer surface and suck in water and food. The water is thrown out into the hollow of the cylinder and flows out through one end, so that the whole colony moves slowly. The colony shines brightly at night.

All salps are filter-feeders and can efficiently trap the tiniest diatoms and protozoa, which cannot be caught even by the finest meshed nets. Scientists study these by centrifuging sea water or by obtaining them from the salp's stomach.

Oikopleura, also related to salps, is very interesting. The head end secretes a gelatinous "house", about the size of a pea, in which the animal lives. The tail end moves so as to produce a current of water which enters through a grating which prevents coarse particles from coming in. The water passes through a filtering apparatus which strains off the finest food particles, and the water flows out at the other end of the house. After a time, when the filter gets clogged or is worn out, the animal throws away its house and secretes a new one in a couple of hours.

Arrow-worms or glass-worms (*Sagitta*) are slender, transparent, dart-shaped predators from one to seven cm long. They are the wolves of the drifters, making up in aggressiveness what they lack in size. (For details, see chapter "Worms that are *not* worms".)

Transparent or red shrimp-like creatures 3 to 5 cm long, called krill or euphausiids, are found in immense numbers in the cold seas where they constitute the food of baleen whales.

While the larvae of almost all marine molluscs are planktonic, there are a few molluscs which pass their entire life as drifters. Prominent among these are the sea butterflies or pteropods, with thin conical shells about 25 mm long and with the foot modified into two wing-like flaps. In some regions, they are so abundant that they form a food for baleen whales and their shells form thick layers on the sea bottom called Pteropod ooze.

The purple sea-snail (*Ianthina*) has a coiled shell, but it floats upside down on the sea surface buoyed up by a raft of mucous-covered bubbles secreted by it. It anaesthetises its prey by squirting fluid at it and then devours it.

Sea slugs live on the sea bed, but one (*Glaucus*) floats upside down on the sea surface, where it feeds on the blue dollar (*Porpita*). It is immune to the stinging cells of its prey and incorporates these into its tissues, so that it is safe from its enemies. After finishing off *Porpita*'s polyps and tentacles, *Glaucus* lays its eggs on the prey's float.

Among the temporary or meroplankton are the aurelia larvae of hydroid coelenterates, trochophore larvae of segmented worms, veliger larvae of bivalve molluscs, nauplius larvae of barnacles, zoaea and megalopa larvae of crabs, phyllosoma of lobsters, bipinnaria of sea-stars, pluteus of sea-urchins, auricularia of sea-cucumbers, pluteus of brittle stars and, last but not the least, fish eggs and larvae.

Although zooplankters have weak powers of swimming and therefore drift horizontally with the currents and tides, they exhibit vertical migrations during daytime and night. This is because they shun very bright light (as on the sea surface at noon) and swim away (i.e. downward) from it. But they swim towards dim light. Thus we find the maximum amount of plankters a little below the sea surface during the day, and none at the surface. This has baffled scientists who found a "false bottom" indicated on their echo-sounders which rose at night and sank during the day. This mysterious phenomenon is called the Deep-Scattering Layer.

Plankton can thus be classified as per the depth at which it is found. Pleuston constitutes plankters which are partly above the sea surface, such as Portuguese man-of-war (*Physalia*) and By-the-wind sailor (*Velella*). Neuston is found in the uppermost few to tens of millimetres below the sea surface. Deeper down, we have the eupelagic (less than 300 metres during daytime), mesopelagic (300 to 1,000 m at daytime), bathypelagic (1,000 to 3,000-4,000 m at daytime) and abyssopelagic (more than 3,000-4,000 metres) plankters.

Plankton can also be classified according to size. For example, megaplankton and macroplankton can be seen by the naked eye. The former is more than 20 mm (such as jellyfish, salps, fish larvae) and the latter from 2 to 20 mm (arrow worms, sea butterflies, large copepods). All these will be retained in a townet with 1 mm mesh aperture. Mesoplankton is from 200 microns (a micron is one-thousandth of a millimetre) to 2 mm (small copepods, cladocerans, rotifers); these can be retained in a net with 0.06 mm mesh. Microplankton is of 20 to 200 microns (phytoplankton, foraminiferans, ciliates). Nannoplankton is from 2 to 20 microns (small diatoms, dinoflagellates, coccolithophores); it has to be centrifuged. Ultraplankton is less than 2 microns (e.g. bacteria).

Collecting plankton using townets is a slow and tedious process; the net would get torn if towed at high speeds as the fine meshes do not allow the water to filter through. This has been overcome by using high-speed devices such as Hardy's continuous plankton recorder which can be towed behind a ship. Here, water enters from a small opening in a long, hollow metal tubular body. A propeller moves a strip of gauze behind the opening. This filters out the plankton which is pressed between two rolls of gauze and then wound on a spool inside a container full of preservative fluid.

Nowadays, multiple net systems such as MOCNESS, BIONESS or RMTI are used. Several nets are mounted on a sturdy frame. Each net can be opened and closed by sending a command signal down a cable to a motor mounted on the frame. Electric sensors mounted on the frame relay information on depth, salinity, water flow, intensity of light, and angle of net via an electric cable.

Scientists not wanting to mess about with dangerous formaline can now use the camera-net system. A camera mounted on the net takes photographs of plankton as they pass through and are illuminated every two seconds by electronic flash. The rolls of film are then scanned to find out the amount and identity of forms; this method is, however, expensive.

The acoustic doppler current profiler (ADCP) has four transducers mounted on the ship's hull which send out narrow pulses of high-frequency sound. The intensity of the returning acoustic signal is related to the density of zooplankton.

Plankton studies came to my help in an unexpected way. After having enjoyed vacations in school and college over the years, my first summer of postgraduation was miserable. While all my friends went swimming in the sea and asked me to join them, there was nothing like a vacation for me. I used to think of these lucky blighters cooling themselves in the water while I was cooped up in a laboratory.

Suddenly a brainwave struck me. I was asked to collect plankton for my studies by towing a net at the end of a long cord while I walked on the sea-wall, with the net many metres below. Next day I carried a bath-towel and swimming costume to work. Going back to my research guide, I told him that the cord had slipped from my hands, and asked for permission to go into the water and retrieve the net. He asked me to be careful not to drown.

After a couple of days, the net again managed to "slip from my hands". My guide raised his eyebrows, with a caustic remark that I was too careless. When I tried this trick again a third time, my guide saw through my mischief, and that put an end to my vacation swims!

7 Miniature Sea-shells

Build thee more stately mansions,
O my soul,
As the swift seasons roll!
Leave thy low-vaulted past!
Let each new temple, nobler than the last,
Shut thee from heaven with a dome more vast
Till thou at last are free,
Leaving thine outgrown shell by life's unresisting sea.

The most primitive animals on earth are tiny, one-celled creatures, of which some, such as *Amoeba* and *Paramoecium* are familiar to every student. Representatives of these also live in the sea, along with the dinoflagellates which botanists claim to be plants and zoologists as animals. The most well known, because of their beautifully sculptured shells, are the members of the Foraminifera and Radiolaria.

The most plentiful Protozoa in the sea are the Foraminifera, called in short as

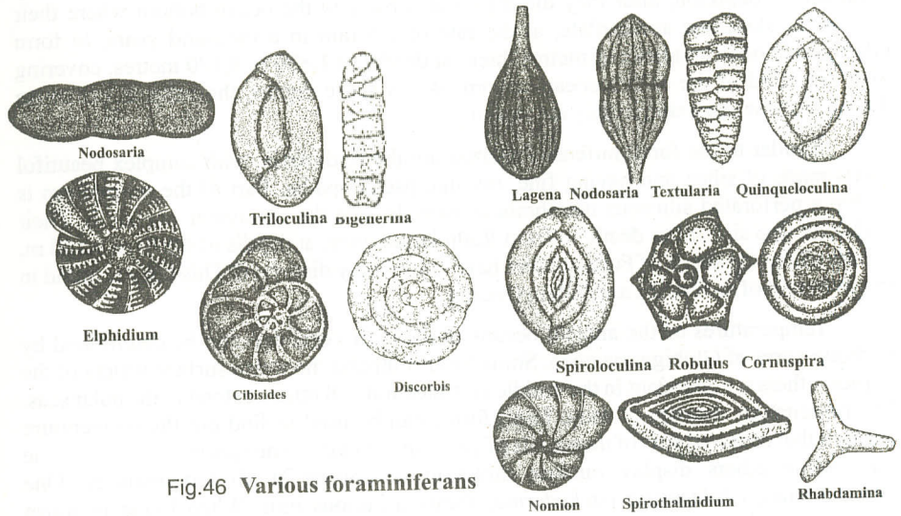


Fig.46 **Various foraminiferans**

"forams". More than 5,09,000 kinds are known, of which about a thousand live today, the rest being fossils.

The "shells"– also called tests– of forams are made from calcium carbonate (lime) extracted from sea water. Unlike snail shells which form a protective "house" for the soft animal, the protoplasm of forams is found inside the shell as well as covering it on the outside. Most foram shells are about a little below (0.85) a millimetre, but their sizes vary from 0.4 mm to 50 mm (for the fossil Nummulites). The shape of the shell varies, being globular, oval, flat or tapering, And it is usually divided into chambers, separated by partitions with holes. (*Lagena* and *Cornnuspira* have only one chamber.) The chambers may be linear (as in *Nodosaria* and *Pleurostomella*), oval (*Triloculina*),

tapered (*Bigenerina*), flat spirals (*Elphidium, Cibicides*) or helical spiral (*Discorbis*).

Almost all forms have large apertures (openings) in the wall of the last chamber, from which the nucleus leaves the shell for reproduction.

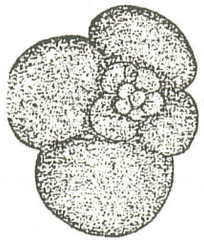


Fig.47 ***Globigerina***

Hence without parent by spontaneous birth
Rise the first specks of animated earth.

This aperture may be round, oval, arched, linear, crescent-shaped or a series of enlarged pores.

The extinct Nummulites and Camerinas had large (5 cm) coin-shaped shells, which are embedded in large numbers in the limestone used for making the pyramids of Egypt.

A few forms make agglutinous or arenaceous shells by sticking silt, sponge spicules or shell particles into chambers. In a few, the shell is made of silica or chitin (a substance similar to our finger nails).Forams feed on diatoms, copepods, larvae and other protozoa. Like *Amoeba*, the protoplasm outside the shell forms threadlike pseidopodia (false feet), surrounds the food as a "feeding cyst" for an hour or so. After digesting the food, the cyst disintegrates and the pseudopodia assume their normal appearance.

Forams live drifting in the plankton; some crawl on the sea bottom or attach to rocks and shells. Most well known in the group are the forams of the genus *Globigerina*. Very abundant in plankton, after they die they sink slowly to the ocean bottom where their calcareous skeletons accumulate, at the rate of 2.5 mm in a thousand years, to form Globigerina ooze hundreds of metres thick, at depths of 1,830 to 4,570 metres, covering over one-third of the earth's ocean bottom. Below these depths, the calcium carbonate dissolves in the sea water, so they are absent.

Similar to the foraminiferan Protozoa are the Radiolaria, with complex beautiful shells made of silica and having fine, ray-like pseludopodia. Part of the protoplasm is within a perforated siliceous membranous capsule, and the remainder outside it. Their skeletons also sink, after death, to form Radiolarian ooze, at depths of 4,570 to 9,150 m, depths where the shells of Foraminifera have completely dissolved. This ooze is found in tropical areas of the Pacific and Indian Oceans.

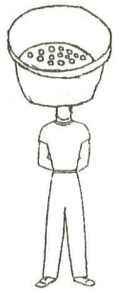
Temperatures of the ancient oceans millions of years ago can be determined by studying cores of Globigerina ooze. Some forams inhabit the warm surface waters of the tropics; others are abundant in the middle latitudes and still others extend to the polar seas. The presence or absence of these fossil forms can be used to find out the temperature changes that occurred tens of thousands of years ago. Again, some species always coil one way, while others display random direction of coiling at all temperatures. One foraminiferan, *Globigerina pachyderma*, shows a curious trait. When living in warm waters, its shell coils to the right, but in cold water it coils to the left. Thus, by examining this species, one can determine when the oceans were warm and when they were cold. The proportion of left- to right-coiling tests can also be used in determining the range of ancient ocean temperatures. Another way of using forams for determining ancient temperatures is by measuring the oxygen isotopes in the shells.

During the last few hundred thousand years of the Pleistocene Epoch- which lasted for a million years and ended only ten to fifteen thousand years ago- there were at least four occasions (called the Ice Ages) when ice covered over 30% of the earth. (Today it covers only 9%, in Antarctica and Greenland.) About 32 million years ago, the water of the Antarctic Ocean was as warm as in temperate seas today, with spruce and pine trees

growing in Greenland. The temperature at the bottom of the Pacific Ocean was then 10ºC; 22 million years ago it had fallen to 6.5ºC, and a million years ago it had fallen further to 1.6ºC, close to the present temperature of the ocean bottom. Prior to the Pleistocene period, the earth had not experienced significant glaciation for some 60 million years.

Fossil foraminiferans are also used in locating oil and natural gas deposits in the bowels of the earth.

8 The Living Sieve



There are a fence with spaces you
Could look through if you wanted to.
An architect who saw this thing
Stood there one summer evening,
Took out the spaces with great care
And built a castle in the air.

Christian Morgenstern

In general, we have a tendency to be interested in things that move, and overlook sessile (immobile) life. On the other hand, sessile animals do not try to run away and hide, so that you can devote as much time and attention to them as your patience lasts. Sponges fall into this category. Until the nineteenth century, they were confused with plants and, later, with coelenterates such as sea anemones, both being called zoophytes (plant-animals). They are the most primitive animals visible to the naked eye, and their body is built up of many cells. But they do not have body organs such as brain, stomach or a mouth.

Sponges are predominantly marine, except for a small family found in lakes and ponds. They grow by spreading and branching in a plant-like manner, and reproduce sexually as well as asexually by special cell masses called gemmules.

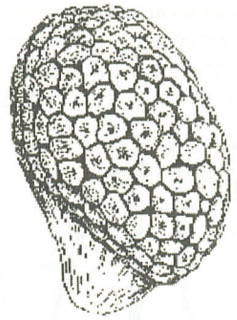
Fig.48 **A collage of sponges ; Neptune's goblet in the centre**

Hircinia *Tedania* *Microciona*

Fig.49

Desmacidon

Fig.50



Tethya

Some sponges may have the shape of a cylinder or vase, but most grow as irregular encrustations on rocks or as flat, rounded or branching structures. There is no particular shape except in the vase-like forms, as the animals mould into the shape of the substratum, being also modified by wave action and water currents. If the water is turbulent they form an encrusting layer on the substratum, but in calm waters they may form finger-like or shrub-like erect branches which may sometimes be a metre high or round. They have many minute pores all over the body called ostia, and fewer larger openings called oscula.

The body is hollow and the body wall is made up of an outer layer of thin flat cells (called pinacocytes) forming the skin or epidermis, and an inner layer of collar cells or choanocytes. These, as the name implies, have a collar surrounding a long, whip-like flagellum which by lashing about, creates a water current. In between these two cell layers is a gelatinous, jelly-like filling called mesenchyme, in which wander cells called amoebocytes. Some of these amoebocytes secrete needle-like spicules (also called sclerites) of silica, lime (calcium carbonate) or fibres made of a horny proteinaceous substance called spongin.

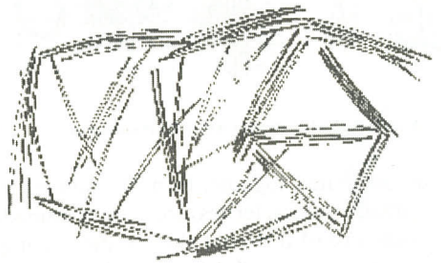


Fig.51 **Needle- like sponge spicules**

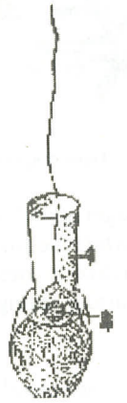


Fig.52 **A collar cell**

The body wall is pierced by many pores called ostia. The ostium is just a hole or tunnel in a pinacocyte cell; such a modified cell is called a porocyte. The beating of the

collar cells creates an incoming water current from the ostia, via a complex system of canals and chambers into the hollow sponge body (called spongocoele), bringing with it oxygen and minute food particles. After removal of the oxygen (for breathing) and the food, the water passes out through the large osculum.

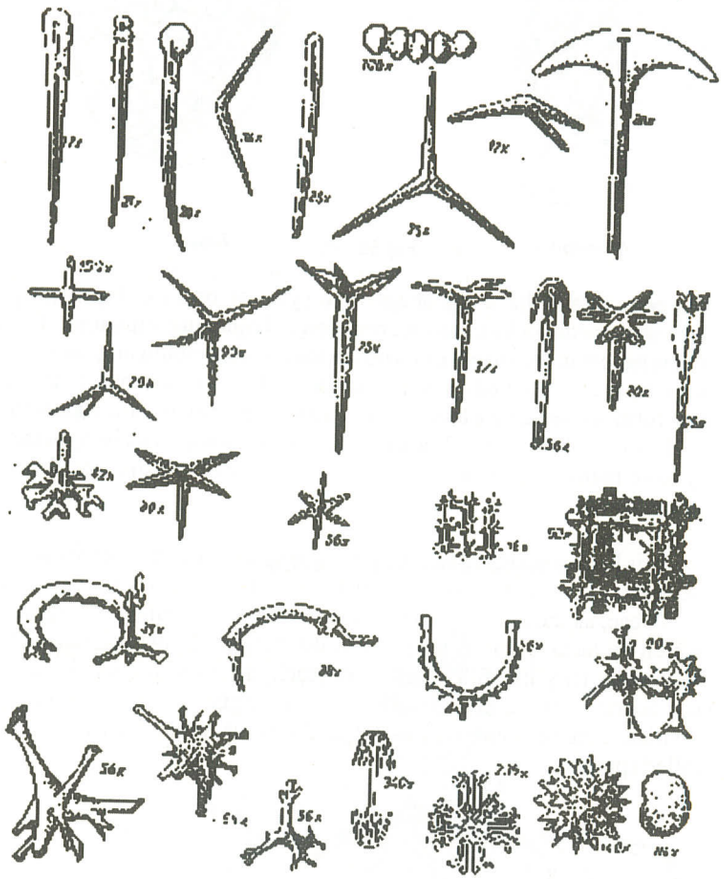


Fig.53 **Types of sponge spicules with their magnifications (After Hartman *et al*)**

The larger spicules, called macrosclerites, together form the support framework of a sponge, while the smaller ones, named micro-sclerites, are loosely embedded in the gelatinous matrix or mesenchyme. They are of different shapes and are important in identifying various sponges, but their study is meant for the specialist, so we shall skip this aspect.

Sponges are mostly drab in appearance, but a few are coloured yellow, orange, red or even blue, violet and black. Those with silica or limy skeletons are rough to the touch, as the tips of the spicules project through their skin. Horny sponges appear leathery, smooth and hard or slimy. But all sponges can be easily distinguished by their porous appearance.

Sponges seem to be disagreeable in taste and smell, hence they are usually shunned as food items. However, dorid nudibranchs (sea slugs) feed on sponges.

As sponges are very low in the ladder of evolution, their powers of generation are high. A broken piece of sponge will grow into a new one. Even if broken up and passed through fine-meshed cloth, the individual cells clump together to form a reunition mass, consisting of amoebocytes and collar cells which have lost their collars. These rearrange themselves to form a new sponge. Even under adverse conditions, a sponge may collapse and disintegrate, leaving behind spherical reduction bodies. When favourable conditions return, these grow into a new sponge.

Apart from having eggs and sperms, many sponges reproduce asexually. A mass of cells collect together and are enclosed in a thin membrane of flat cells, the gemmule. The flat cells, except at the rear end, grow flagella and the larva swims away to settle on a substratum, lose the flagella and grow into a young sponge.

The boring sponges (*Cliona*) bore into corals, clams and barnacles. A coral head one metre high, after being attacked by *Cliona* can crumble to coral sand in a century.

Although sponges normally stay put at one place, some species such as the chicken-liver sponge (*Chondrilla*) up to 25 cm in diameter can move at speeds up to 4 mm per day. They form flattened protrusions of tissue, which contain active cells called pinacocytes. Located at the sponge's leading margins, these cells crawl away from the initial attachment site and drag the sponge along with them.

Sponges play host to a variety of animals, both for support and shelter. Hydroids (zoophytes), moss-animals (Polyzoa) and barnacles may grow on them. Worms, brittle stars and pistol shrimps live inside sponges, protected from enemies and bathed by oxygenated water bringing food particles. (A large loggerhead sponge was found to shelter 16,352 pistol shrimps.) Venus's Flower Basket (a deep-sea sponge) often contains a pair of Stenopid shrimps, *Spongicola*. They enter the sponge body when young and, in their sheltered life, cannot escape (even if they want to) because they grow too large to escape. The osculum of this sponge is closed by a perforated sieve-plate. They thus live their entire life voluntarily imprisoned within the sponge.

Fig.54 **Venus's flower basket**

As Lear said to Cordelia when taken prisoner:

> Come, let's away to prison
> We two alone will sing like birds in the cage.

The Japanese give such sponges containing a captive pair of shrimps as gifts to newly wedded couples, as they symbolise a marriage lasting until death. The Japanese name for this sponge means "Together unto old age and into the same grave".

The sponge-crab *Dromia* carries a live sponge on its back, keeping it in place by holding it with its last pair of legs. Decorator crabs (spider crabs such as *Paramithrax*) break off pieces of sponge, seaweeds and hydroids and place them on the spines on the back, where they stick and continue to grow. The crab looks like a walking garden. Some hermit crabs also place a piece of sponge on the (dead) snail shell in which they shelter. The sponge grows all over the shell except at its opening. In due course, the shell dissolves and the hermit crab is covered only by the live sponge.

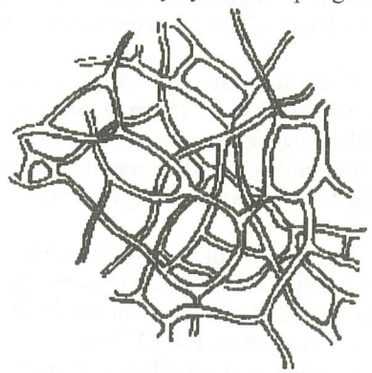


Fig.55 **Spongin fibres of bath sponge**

The bath sponge, once familiar in all households, has a skeleton of spongin fibres without any limy or silica spicules. Spongin belongs to the sulphur-containing group of proteins called keratins, found in hair, nails, horn, feathers, reptile scales (eukeratins), our skin, nervous system, sponges and sea-fans (pseudokeratins). Silk and collagens (found in connective tissue and which yield gelatine when cooked) are other forms of keratins.

Bath sponges grow in the eastern Mediterranean and Aegean Seas as well as in Bahama Is., Gulf of Mexico and Florida. Sponging (collecting sponges) is done by hooking them with a pole ending in a four-pronged hook, or by divers. Sponging in the Mediterranean Sea has been carried out for thousands of years; skin diving for sponges was one of the items in the Athenian Olympic games. In 1841, a French merchant saw natives in the Bahamas using sponges, and a new industry was born. In 1939, and again in 1947, disaster struck the American sponge fishery in the form of a blight which killed the sponges there, but it is slowly recovering.

Bath sponges, after being brought up on the boat, are trampled with bare feet, then piled up base downward, to drain and are covered with gunny cloth. Later, they are alternately squeezed and washed many times, the outer skin scraped off, and they are

strung 150 sponges on a line. On shore, they are sorted, graded and re-strung on 1.5-metre long string into loops for sale.

Natural sponges are far superior to the synthetic "sponges" made of cellulose, neoprene or vinyl. They are firm yet pliable, rigid yet resilient, and can be squeezed but will spring back to their original shape. Their inner network of chambers connected by channels can hold a large amount of water. Spongin is noted for its insolubility, chemical inertness and resistance to enzymes digesting protein. It does not melt or burn, so the sponges can be sterilised in boiling water for medical use in hospitals, and in cannon and rockets. Apart from the familiar use for scrubbing our body while taking a bath and for washing cars and boats, they are used by artists and painters, lithographers, tile setters, ceramic and leather workers.

9 On the Rocks–but not whisky

The living flowers that, rooted to the rock,
Late from the thinner element,
Shrunk down within their purple stems to sleep,
Now feel the water, and again
Awakening, blossom out
All their green anther'd necks.

A step higher than sponges in the tree of evolution is a motley group of animals which scientists call Coelenterata. While some of these, such as sea anemones and jellyfish are well known, others are likely to be missed due to their small size and sessile (immobile) nature.

The three classes of Coelenterates comprise: (1) the hydroids, (2) jellyfish (or medusae) and (3) sea anemones/corals. The first group is also known as zoophytes (meaning animal-plants) as they were confused by early scientists as plants. And this confusion can well be understood if we see these feathery objects horny in texture and of a pale yellowish-brown colour, among seaweeds washed up on the shore. But their real beauty is seen when we place them in sea water or see the living forms in a tide pool, attached to rocks or seaweeds.

A magnifying glass reveals tiny semi-transparent cups or goblets from which spring tiny flower-like creatures with a whorl of finger-like "petals". In other forms, the "flowers" are naked, i.e. they are not enclosed by cups. The feathery bunch is a hydroid colony.

Colonial existence is the rule in almost all sessile animals. In our commonly known animals, life begins as an egg which, after being fertilised by a sperm, starts to grow and ends up as an individual adult. This is called sexual reproduction, as two sexes (male producing sperms, and female producing eggs) are involved. But others, mainly sessile forms split in two (like budding in plants). The two remain attached to each other, more buds are produced, ultimately leading to a "colony" of similar-looking individuals. A hydroid colony consists of stems and branches with an outer, hollow semi-transparent sheath (called perisarc), inside which is a pith (called coenosarc) running into all the branches.

At intervals along the branches are the individual animals called zooids, hydranths or polyps (also spelt polypes). Each polyp has a circlet or crown of tentacles, which help to collect food and then, acting like fingers, push the food into the central mouth.

As in all coelenterates, the hydroid polyp is made up of two layers—an outer one (called ectoderm) forming the skin, and which secretes (in hydroids) a horny protective layer, and an inner one that lines a hollow space which acts as a stomach; this is the only cavity that a polyp has. Food is digested here and the undigested portions are thrown out from the mouth, there being no intestine ending in an anus. The advantage of being a colony of animals is that the food is distributed to all individuals (polyps) even if some polyps are successful in capturing food while others could not find any; the latter will not go hungry. If you see a live hydroid colony under a microscope, you will find that a stream of digested food particles goes from the bottom of the polyp into the tubular pith or coenosarc of the colony, to reach other (hungry) polyps.

Between the outer ectoderm (skin) layer and the inner endoderm layer of cells is a jelly-like substance; this jelly layer is very thin in hydroids. The three-layered body is characteristic of all coelenterates, but the jelly-layer is very thick in jellyfish, while it is thicker and fibrous in sea anemones.

Stinging cell. Fig.56 **Same, discharged.**

All coelenterates, including hydroids, have another peculiar characteristic radial symmetry. In an animal such as a dog or a human, we speak of a head or front end, a tail or hind end, and left or right sides; in short, a bilateral symmetry, where the left and right halves are similar. A coelenterate does not have a front or rear end, nor does it have left or right sides. Instead of a bilateral symmetry, we have a radial symmetry. Just as you can cut a cake into symmetrical slices or sections, you can divide a polyp, a jellyfish or sea anemone along several radii into equal or symmetrical parts.

There is another feature common among all coelenterates; they all have tiny stinging cells (also called nematocysts), which are peculiar to this phylum. Each cell has a hollow cavity filled with a poisonous fluid and containing a coiled hollow thread. On the slightest touch, the thread is shot out and injects the poison. When we are at the receiving end, we say we are stung, but a minute animal or fish gets paralysed and dies. These stinging cells serve to protect coelenterates against enemies as well as enable them to catch their food. There are many kinds of such stinging cells, and as each coelenterate has only particular kinds, these help in identifying the animal. Some stinging cells, instead of having a poison sac, have the thread sticky; these hold on to small prey and prevent its escape.

Another peculiarity in hydroids and jellyfish (but not in sea anemones and corals) is the alternation of generations. As we saw earlier, the colony is formed by (asexual) budding of the animals. But, sooner or later, besides the tentacle-crowned polyps (alimentary zooids) there appear differently shaped generative polyps, also called blastostyles. These lack tentacles, and are the sexual polyps. These now form a saucer- or umbrella-shaped "medusa" which detaches from the hydroid colony to swim away. Some medusae produce sperms, while others produce ova (eggs). After fertilisation, the egg grows into a larva (baby) called planula, which has many hairs, called cilia. With the help of these cilia, the planula larva swims away. After some time, the planula settles on a suitable substratum such as stones, seashells or seaweeds and starts a new colony of hydroids. Thus we have an asexual generation of sessile polyps lasting for a long time,

alternating with a sexual generation of swimming medusae for a much shorter, transient period.

Coelenterates are the most primitive animals to have muscles. (Sponges do not have any.) Hydroids use muscles to expand or contract and to move their tentacles.

There are two main groups of Hydroids: the naked (also called (athecate) Gymnoblastea, and the thecate Calyptoblastea.

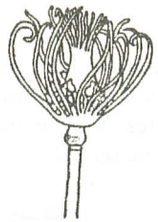
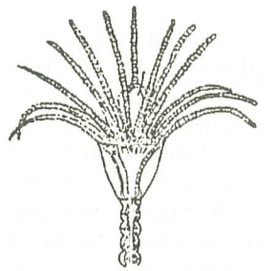


Fig.57 **Naked polyp (Gymnoblastea)**

In the Gymnoblastea, the polyps are not protected inside cup-shaped sheaths. The polyps are larger than in the thecate group. *Tubularia* is one of the bigger athecates. Its colony is not branched, but clusters of pink flower-like polyps arise from stalks about 8 cm long. The two whorls of tentacles are filiform, i.e., tapering towards the tip. *Pennaria* has the typical feathery colonies; the main stem is about 20 cm long and bears shorter (2 cm) lateral branches on either side. In addition to the filiform tentacles at the base of the polyp, there are capitate (club-shaped, with swollen, knob-like tips) tentacles around the mouth. *Eudendrium* has only one circlet of filiform tentacles. In *Syncoryne* the capitate tentacles do not form a circlet but are scattered all over the polyp.



Polyp inside a cup like hydrotheca (Calyptoblastea)
Fig.58

Fig.59 **Colonies of *Sertularella*, showing variations in branching**

In the Calyptoblastea, the thin horny protective sheath (called perisarc) covering the branches expands into cups around the polyps. In *Obelia*, the polyps are borne on stalks on alternate sides of the stem, which therefore has a zigzag appearance. The perisarc at the base of the polyp has 8 to 10 rings.

In *Plumularia* and *Sertularia*, the cups are not borne on stalks, but are sessile, arising directly from the stem. The former genus has the sessile polyps only along one side of the stem, while in the latter the polyps are opposite each other on both sides of the stem. *Sertularia* gives a painful sting like that of a red ant.

The Millepores, typified by the fire- or stinging corals (*Millepora*) have a

massive skeleton of calcium carbonate. The upright leaf- like calcareous growths reach a height of 30 to 60 cm in shallow water down to 30 m, and are a regular component of tropical coral reefs. The surface is pitted with pores of two sizes, the larger ones holding the digestive polyps (gastrozooids) and the smaller ones containing the polyps which capture prey (dactylozooids). Their name comes from the powerful stinging cells which can leave a red weal on our skin.

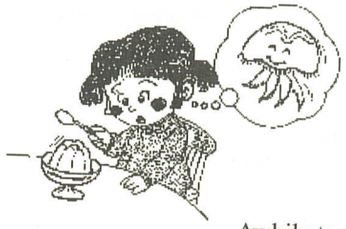
In another order, called Trachylina, the polyp generation may be reduced or even absent, so that medusae dominate. These may look remarakably similar to the true jellyfish (to a lay person), but these latter belong to a different class altogether. Examples are *Aglantha, Geryonia* and *Olindias*.

In yet another order, the siphonophores, there is a very high degree of polymorphism, that is, the individual animals comprising a colony have different functions, such as capture of prey, digestion, reproduction and flotation. The best known forms, such as *Abyla, Agalma, Diphyes, Muggiaea, Nectalia* and *Stephalia* have a float and/or many swimming bells, below which trail the other polyps. The Portuguese man-of-war (*Physalia*), blue dollar (*Porpita*) and by-the-wind sailor (*Velella*) also belong to the Siphonophora; they will be treated in a subsequent chapter.

Probably the most exalted student of hydroids was Emperor Hirohito of Japan; when not busy with affairs of state he spent at least part of two or three days each week in a laboratory built specially for his use on the grounds of the Imperial Palace, Tokyo in 1925. From 1967 onwards, he published a series of scientific papers, culminating in his monograph The Hydroids of Sagami Bay in 1988.

He must have probably been drawn to these animals by the discovery, in 1875 during his grandfather's reign, of the largest hydroid in the world. Named *Branchiocerianthus imperator*, it measured an incredible 2.23 metres and was obtained off Japan.

10 The Living Jellies



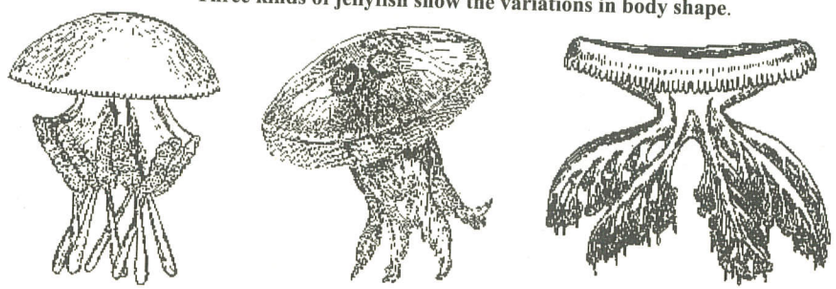
Awhile to wait upon the firm fair sand,
When all is calm at sea, all still at land;
And there the ocean's produce to explore,
As floating by, or rolling on the shore;
Those living jellies which the flesh inflame,
Fierce as a nettle, and from that its name;
Some in huge masses, some that you may bring
In the small compass of a lady's ring;
Figured by hand Divine there's not a gem
Wrought by man's art, to be compared to them;
Soft, brilliant, tender, through the wave they glow,
And make the moonbeam brighter where they flow.

George Crabbe

You will often find jellyfish washed up on the beach. With a soft, gelatinous consistency and translucence resembling the inner pulp of the fruit of the palmyra palm (*tadgola*), jellyfish are up to 95% water. If you observe a freshly dead individual and then see it the next day, you cannot fail to notice how much it has shrunk. If you keep a small one on a sheet of paper, you may see only a stain-mark on the paper after some days.

There are some 200 species of jellyfish, all of which are marine. Jellyfish swim by contracting their body some 120 to 150 times a minute. The general shape of the body, called a bell or umbrella, varies from a shallow saucer, bowl or goblet to a dome or trumpet. Unlike the medusae of Hydrozoa, which have a velum—an incurved flap of tissue running around the rim of the bell, jellyfish lack a velum.

Three kinds of jellyfish show the variations in body shape.



Aurelia *Mastigias* *Cassiopeia*

Fig.60

On the lower surface of the bell hangs a squarish tube, called manubrium, at the end of which is the mouth. This leads to a large stomach with four pouches. All round the margin of the bell are tentacles armed with stinging cells, and at regular intervals there are eight notches in the bell, each having a spot-like mark protected by two flaps. Called eye-spots, these are primitive eyes which cannot "see" as we do but can detect light and shade. Through the translucent body you can see four pinkish or orange U- or horseshoe-shaped organs. These are the gonads (testes or ovaries, depending on the sex of the jellyfish).

As in all coelenterates, there are two layers of cells–the ectoderm (or skin) and endoderm, but unlike hydroids and sea anemones the jelly-like mass between these two is very thick in jellyfish, giving them the typical jelly-like consistency. Jellyfish swim by opening and closing their bell-like body. Their size varies from 10 cm to over a metre in diameter, the latter having tentacles up to 23 m long.

As in hydroids, there is an alternation of generations in jellyfish too. In the breeding season, the reproductive organs release their ova or sperms into the stomach cavity, from where they emerge via the mouth into the sea. After fertilisation, the eggs grow into a planula larva which swims by means of its cilia (tiny hairs). After some time, it descends to the sea bottom, becomes attached and grows into a polyp. But, whereas in hydroids the polyp buds off to form a branching colony, the jellyfish polyp forms a series of constrictions, looking like a stack of saucers but with deeply notched rims, called Ephyra. Each ephyra now detaches from the parent polyp and swims away to become a jellyfish. Thus, while in the hydroids the asexual polyps are dominant with the sexual medusa being only a temporary stage in the alternation of generations, in the jellyfish it is reversed, the polyp being a transient stage in their life history, while the sexual medusa stage (i.e. jellyfish) is dominant.

Fig.61

Strobilation is the process of budding off of young jellyfish from the stack.(After Hyman,from Galigher)

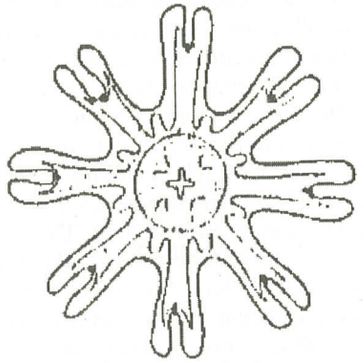


Fig.62 **Ephyra detached from a strobila (After Hyman,from Galigher)**

In some years there is a population explosion or "bloom" of jellyfish which, to say the least, is a terrible nuisance to fishermen as they clog their nets and sting badly while being removed. I remember one such bloom which affected the cooling system of an atomic power station producing electricity. They clogged the rolling screens and stung the workers who were removing them, even though they were wearing gloves. I was called to suggest a way out.

Used to high-tech solutions, they thought of shocking the jellyfish with electric current, or frightening them away with loud sounds or ultrasound. Neither of these would have worked. Electric current would be fatal if anyone dipped his hand. (Sea water is a good conductor of electricity.) Moreover, the dead jellyfish would still be carried to the screens by the flow of water. And they do not have ears to hear sounds and stay away. Ultrasound would break their bodies into pieces which would still be carried to the screen and sting the workers. My remedy was primitive and simple but proved effective. Have three nets strung at intervals along the cooling water channel, acting as barriers to block the jellyfish. When the first net got clogged, take it out and dry it, so that the dead jellyfish will shrink, shrivel and fall off. In the meanwhile, the second net will act back as a barrier, after which the first net can be put in place. The third net was a final barrier if the first two were both out of the water. This method worked fine.

The sting from Cubomedusae is often fatal to humans within minutes (After Haeckel)

Fig.63

All jellyfish sting badly, and the stings of some, like *Carybdea* or *Chiropsalmus*, can be fatal to humans. The effect of their stinging cells resembles that of the cow-itch (from the Sanskrit *kavach*) plant (scientific name *Mucuna prunens*). But some jellyfish called sea wasps or Cubomedusae (from their cube-shaped body) can prove fatal to humans within five minutes. Even when diluted 10,000 times and injected into mice, it kills within seconds. The venom causes the victim's blood cells to break down and death comes by asphyxiation. The sea-nettle (*Chrysaora*), sea wasp (*Chironex*), lion's mane jellyfish (*Cyanea*), and mauve stinger (*Pelagia*) are all dangerous to humans. The moon jelly (*Aurelia aurita*) delivers a sting which is itchy, tingly and uncomfortable, but not dangerous. It should be remembered that different people have different tolerances and reactions. Thus, a sting that may give one swimmer only a nasty welt may put another person into shock and result in drowning. The stinging cells or nematocysts of coelenterates are of many different kinds, and are used by scientists for identifying different animals, as each kind of coelenterate has only a limited variety (normally up to four) of nematocysts.

In spite of the danger from the stinging cells, the young of some fish take shelter under the bell and may even eat the jellyfish's ovaries and eggs, oral frill and even tentacles. The spider crab *Labinia* lives only in the manubrium of the jellyfish *Stomolophus*.

We also have other jellyfish-like animals, but without stinging cells, in the sea. These are placed in a separate phylum called Ctenophora or comb-jellies. As the name implies, their body has eight rows of comb-plates, each plate having tooth-like hairs (cilia) projecting from its free edge. The animal swims by a continuous movement of the cilia.

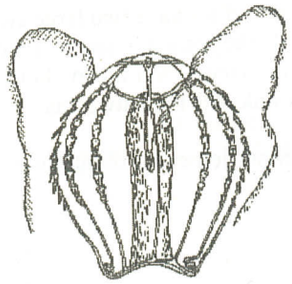


Fig.64 **Sea - gooseberry**

Of the various comb-jellies, the commonest are the sea-gooseberries (*Hormiphora, Pleurobrachia*). On either side of the pear-like transparent body are two long branched tentacles. The mouth is at the pointed end of the "pear" and there is a sense-organ at the other, rounded end. Between these run the eight comb-like plates. The beating of cilia and the subsequent breaking up of light rays by the tiny teeth causes a series of prismatic colours of the rainbow rhythmically over the animal. There is no alternation of generations, the cydippia larva growing into a juvenile with the body shape of the adult.

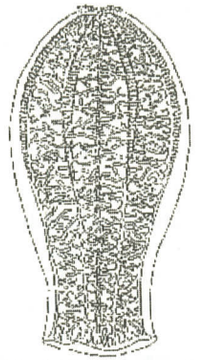


Fig.65 **Sea thimble (After Hyman)**

The sea-thimble (*Beroe*) has a body shaped like a thimble or a bishop's mitre, with the typical eight rows of comb-plates. The animal has a complex network of canals which are seen through the transparent body. The 3 cm-long animal has a pinkish tinge. The mouth is very wide and there are no tentacles.

Fig.66 **Venus's girdle**

Venus' girdle (*Cestum, Folia*) is a transparent bluish flat ribbon many feet long. The stomach is situated in the middle of the ribbon. It swims by continuously rolling up and then unrolling its body. The tentacles form a double fringe along the upper and lower edges, and their movement sends bands of prismatic, rainbow-like hues along the border.

Other, less known comb-jellies have two large symmetrical flap-like oral lobes which, by their flapping, enable the animal to swim. Yet others are vertically flattened, lack comb-plates (except in the larva), and creep about on the sea-bottom. They are believed to be an evolutionary link with the flatworms.

Many jellyfishes and comb-jellies are bioluminescent and shine in the dark.

11 Borne on the Purple Wind

This is the ship of air, which poets feign,
Sails the unshadowed main
The venturous barque that flings
On the sweet summer wind its purpled wings
In gulfs enchanted, where the siren sings,
And coral reefs lie bare,
Where the cold sea-maids rise to sun their streaming hair

Oliver Wendell Holmes

Before the monsoon sets in, people on our coasts flock to the seashore to escape the summer heat and enjoy the brisk onshore wind that blows in from the sea. This wind blows a multitude of small animals onto our beaches, which normally would be seen only by sailors and fishermen.

In late May or early June, you might see numerous translucent, iridescent, violet-blue, elongated 'balloons' strewn on the beach. Most of them are around four centimetres long, but a few may be as large as 13 cm. Be wary of picking one up; it is the notorious Portuguese man-of-war. (People in India also call it a bluebottle, but the latter name is more properly attributed to the horsefly.)

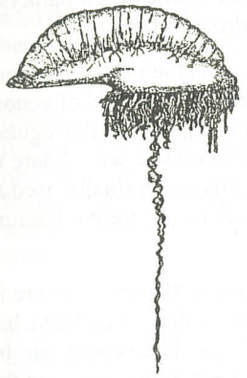


Fig.67 A Portuguese man- of- war

In water, the brilliantly coloured purple, blue, crimson or pink bladder floats on the sea surface. On the top of the float is a flattened inflated crest. We need not stretch our imagination too much to liken the float to a miniature sailing ship with the crest acting as a sail. As a sudden breeze ruffles the sea surface, the float changes shape. In fact, the animal is not blown helplessly before the wind; like a sailboat, it can 'tack' and thereby move at an angle to the wind. In the aquarium, I have seen the animal frequently roll its float under the water to wet its entire surface and prevent it from drying.

Surprisingly, the float is not filled with air but has up to 28% carbon monoxide in it. (This gas is found only in trace amounts in unpolluted air and is almost insoluble in water.) A special gas gland in the animal produces the gas and secretes it into the float. The rest of the gas in the float is air that enters the float through diffusion.

Hanging down below the float is a cluster of blue, green and pink finger-like protruberances, with one very long and a few much shorter dark blue threads. A Portuguese man-of-war is not, strictly speaking, a single animal, but a cooperative society or colony of connected individuals, each of a different shape, and serving various functions. The blue, tube-shaped members are for feeding and digesting the food which is then shared by all members of the colony. The green, tapering fingers are feelers and tasters, and the finely divided pink clusters bear the sex organs.

In the Portuguese man-of-war *Physalia physalis* found in the Atlantic Ocean, there are many long streamers, but in *Physalia utriculus*, which lives in the Indian and

Pacific Oceans, there is only one long (12 metres in an animal with a 13 cm long float) filament with a few much shorter ones. The Atlantic form is much larger, with a float up to 35 cm and the filaments extending to 30 metres. In the live animal, these long fishing tentacles continuously extend and contract; a tentacle which has extended to 12 metres will soon contract to less than a metre. The tentacles are beaded at regular intervals. Each kidney-shaped "bead" consists of some 500 large, and 2,000 small globules. These are the stinging cells.

Each stinging cell is a fluid-filled bladder-like capsule containing a hollow coiled tube. Outside the capsule is a hair-like trigger. When a tentacle comes in contact with a prey animal (or a human), the inner coiled tube is everted with force; this is 20 to 50 times the size of the stinging cell. Venom is injected from a tiny opening at its tip with sufficient force to penetrate clothing or even a rubber surgical glove.

I have been stung on many occasions by a Portuguese man-of-war. It feels as if you have been struck by a red-hot whip which also carries an electric current. The venom is a neurotoxin similar to that of the cobra. Immediately, along the arm where the tentacle had struck, appeared red weals; my arm swelled up to the elbow, my armpit ached where the venom had spread to the lymph glands, and I could not sleep that night. Fortunately the animals we come across at Bombay are small, with only one tentacle. Victims of the larger Atlantic species, who have encountered numerous tentacles of an individual animal, have suffered severe pain and headache, swelling, cold sweat, nausea, vomiting and abdominal pain, muscular cramps, a feeling of nervousness and faintness, hysteria, chills and fever, laboured breathing and sometimes even paralysis and collapse. The intense pain is due to a chemical called 5-hydroxytryptamine.

Weight for weight, except for a few jellyfishes, *Physalia* is the most dangerous animal in the sea. Its venom is as potent as a cobra's; it requires just 0.037 ml of venom per kilogram weight of a human to kill. We should thank our stars that the Portuguese man-of-war cannot inject as much venom as a snake, otherwise no one would dare to swim in the season when the animals abound. The stinging cells are normally used to catch its prey, such as fish. These are stung to death and then drawn up by the contracting tentacles to the feeding polyps.

Since the stinging cells continue releasing venom as long as the tentacles are in contact with the skin, they should be immediately removed, not with the bare hand, but by rubbing with sand, clothing, towels, seaweed or gunny bags. The venom can be inactivated by bathing the affected part in water heated to 60°C (but this can scald the skin), or with spirit, alcohol (whisky will do), suntan lotion, calamine lotion, petrol or kerosene. As the venom is acidic, the best remedy is to apply alkaline substances such as ammonia, milk of magnesia, solution in fresh water of baking soda or even crushed antacid tablets. Hot water is known to burst the capsule wall of stinging cells, thereby preventing them from discharging. However, the water temperature must be 46° to 48° C. If the water is not hot enough, it will cause more harm because, at lower temperatures fresh water stimulates the stinging cells to discharge. The venom will continue to do harm even after the animal has been washed up on the beach, died and dried up. Moreover, the floats are prettily coloured, and may tempt a child (or even an adult) to pick them up. If at all you must pick one up, use tweezers. After heavy rain with stormy winds, large numbers of tentacles broken off from the animals by wave action may drift in the water, so avoid swimming at that time.

Surprisingly, a fish called *Nomeus* chooses to associate with the Portuguese man-of-war. This bluish to purplish fish is found swimming around and under its tentacles, never straying far. When threatened by other fishes, it swims among the tentacles, safe from its enemies, which respect the *Physalia*'s powerful sting. *Nomeus* appears to be immune to their sting, though occasionally they have been found partly digested, clutched in the tentacles. The fish has at least one antibody in its blood which helps counter the effect of the poison. This, coupled with a highly developed talent for avoiding the tentacles, is apparently sufficient to render the fish relatively safe. They get shelter and protection, and probably repay their host's generosity by acting as a lure for larger fish preyed upon by *Physalia*, and doubtless join in at the feast. The young of one species of octopus pick up broken fragments of *Physalia* and hold them in their arms to ward off enemies.

With an armament so powerful, one would think that the Portuguese man-of-war has no enemies. But hawksbill turtles and the ocean sunfish (*Mola mola*) feed on them. So does the violet sea snail *Ianthina*, which blows gas bubbles and coats them with slime so as to form a floating raft. While feeding, the snail emits a purple dye, which probably neutralises the venom of the *Physalia* or inhibits the stinging cell from discharging.

I had the privilege of discovering yet another predator of the Portuguese man-of-war. It happened this way. Once in a while, during the rainy season fishermen would bring a live specimen of the scribbled leather-jacket *Alutera scripta* and the yellow-finned leather-jacket *Alutera monoceros*. These fishes have been caught at Bombay only when the Portuguese men-of-war are washed up on the seashore (May-June). They are slow, inefficient swimmers, and I wondered how they were able to catch their food. We tried to feed them an assortment of diets, but they seemed to be very choosy in feeding, and soon became emanciated and died.

One day a fisherman brought a live specimen and, as I was busy, I asked him to release it in a vacant tank in the next room. When he returned, he told me that he had released it in a tank where there were many floating 'balloons'. He meant *Physalia*, and I rushed to the tank, expecting that the fish would, by now, have been killed by the Portuguese man-of-war. What I saw was a pleasant shock. In the few minutes that the fish was in the tank, it had nibbled off all the tentacles of the *Physalia*, leaving only the floats uneaten!

Juvenile filefish (*Alutera, Monacanthus*) have extremely thin bodies, with dark, irregular colour patterns that serve as camouflage. They often swim on their sides to mimic floating leaves and mats of algae in shallow water.

The other two animals which I now describe are not dangerous to us. Though they do have stinging cells, their venom is not so potent, so that they are harmful only to the minute prey organisms on which they feed.

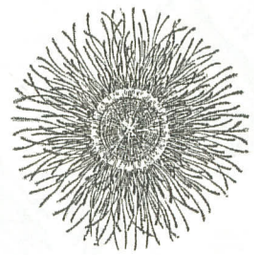


Fig.68 **Blue dollar (*Porpita*)**

Porpita has a flat disc-shaped whitish float made of chitin (the material which forms the shell of prawns) and divided into many chambers filled with gas. Around the central float are numerous dark blue tentacles armed with knobs of stinging cells. Below the disc hang the various types of polyps. Though most of the animals washed up on our beaches have their central disc the size of a 50 paise or one rupee coin and are dark blue, the animal can grow to five centimetres. Very rarely it is coloured lemon yellow. For four decades I had been searching literature for a common name, but all authors called it by its scientific name. Finally, in one solitary reference, I found it described as a "blue dollar"

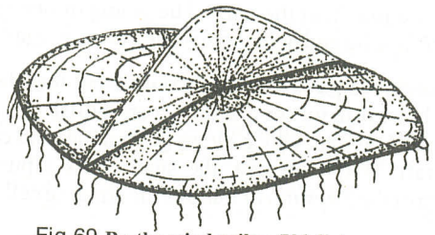


Fig.69 **By-the-wind-sailor *(Velella)***

The by-the-wind-sailor or purple-sail (*Velella*) resembles *Porpita*, but the central disc is oval in shape, not circular, and above it projects a triangular crest enabling it to sail across the wind. Though the adult (3 cm) floats on the sea surface, the young live in deep water. It, too, is dark blue. It has numerous enemies. The purple snail *lanthina*, which feeds on the Portuguese man-of-war, also eats *Velella*, and so do two sea slugs *Glaucus* and *Fiona. Glaucus* has a frilled silvery and blue or black body 3 cm long, and it floats upside down on the sea surface by swallowing air. *Fiona*, however, feeds only on the top surface and sail of *Velella*, refusing to browse the tentacles or below the surface of the float. An isopod crustacean, *Idothea*, also feeds on the by-the-wind-sailor.

Both *Physalia* and *Valella* have the peculiarity of being dimorphic, i.e., those of the northern and southern hemispheres are mirror images of each other, so that their sails are trimmed to the prevailing equatorial winds, which also are contrary to each other in the two hemispheres. Just like Portuguese man-of-war, by-the-wind-sailors also have the sail angled to the right in some individuals, and others to the left. The direction of travel varies accordingly, so that most *Velella* washed ashore in the northern hemisphere are "left-handed", and in the southern hemisphere "right-handed".

All the three animals described above live in the tropics. They are siphonophores, as are the salps, being related to sea anemones, corals and jelly fishes.

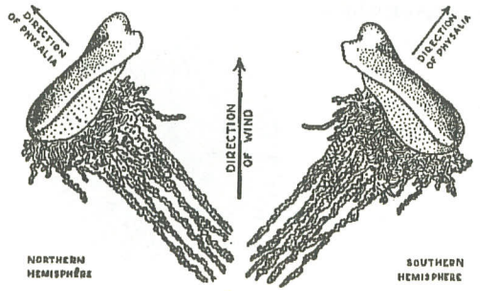


Fig.70 **Sideways twist of Portuguese man-of-war's float**

A peculiarity of *Physalia* is that their sail, instead of being symmetrically placed along the float, is placed diagonally. (The same is the case with the by-the-wind sailor *Velella*.) In Portuguese men-of-war of the northern hemisphere, the float runs from front right to rear left, but in southern hemisphere *Physalia* it is set from front left to rear right. The reason may not be immediately apparent, but it plays a vital role in the animals' survival, as was deduced by A.H. Woodcock. It is the result of physical forces acting on air and water.

This action of wind on the water results in several parallel lines of "windrows", made up of seaweeds and debris, where water from both sides of a windrow meets and then sinks. Between the windrows is a patch of water where two adjacent water masses come up from the depths and then move away from one another at the water surface.

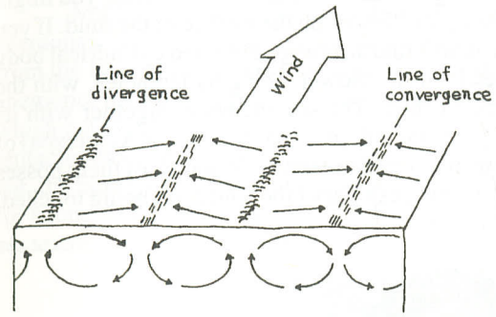


Fig. 71
Langmuir circulation caused by wind

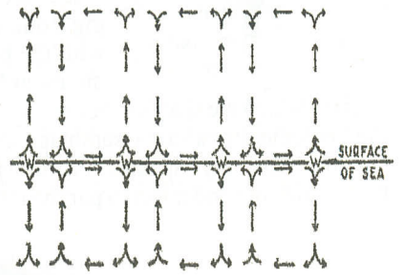


Fig. 72
Formation of windrows on sea surface

If *Physalia* had a symmetrical float, they would drift with the wind and, sooner or later, gather together at a windrow. Since the surface water is sinking here, it is also taking away floating plankton down with it, so that *Physalia* will have poor feeding here. Moreover, they will get tangled in the debris and perish.

A right-handed *Physalia*, in the northern hemisphere, will float in a sinuous path (from A to B in the illustration) where it will spend more time in the food-rich region of upwelling water between the windrows. And so will a left-handed *Physalia* in the southern hemisphere.

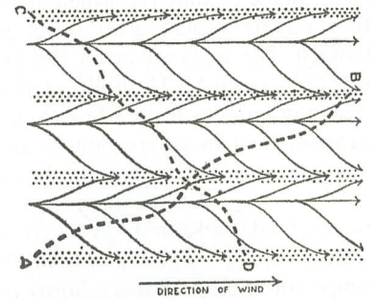


Fig. 73 **Course of Portuguese man- of- war through windrows**

A problem can arise when a left-handed *Physalia* from the southern hemisphere at the Equator drifts into the northern hemisphere. Because of the twist in its float, it will cross windrows more frequently (see the path C-D as against A-B), thus having a greater risk of getting entangled in a windrow. A northern hemisphere *Physalia* drifting across the Equator into the southern hemisphere will face the same problem.

12 Flower Power

And if ye doubt the tale I tell,
Steer through the South Pacific swell;
Go where the branching coral hives
Unending strife of endless lives.

Rudyard Kipling

If you are taking a walk on a mudflat at low tide, you might come across a pink 'flower' on the surface of the mud. If you dig it out, you will find an orange-coloured cylindrical body with the petals of the 'flower' being its tentacles, with the mouth at their centre. The sea anemone, together with its cousins which we shall see below, belongs to the sub-group Anthozoa (or Actinozoa) of the Coelenterates a vast assemblage with one common feature, in that all of them posses stinging cells, tiny capsules containing a coiled capillary tube which, on being touched, turns inside out and injects a paralysing poison.

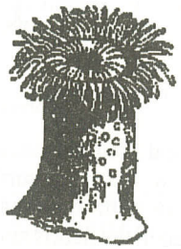


Fig.74 **A typical sea anemone**

Depending on whether the tentacles number six or eight (or, sometimes, ten) or their multiples, the Anthozoa are divided into the Hexacorallina (Zoantharia) and the Octocorallina (Alcyonaria). In the Zoantharia, which include sea anemones and true or stony corals, the tube-like body has septa (partitions) projecting inward from the body wall into the central stomach. The septa are never eight or its multiple; they occur in pairs and may be complete or incomplete. The hollow tentacles may be in one or several circlets, and the tentacles may number from a few (in corals) to hundreds or even a thousand or more (in sea anemones). In sea anemones, each circlet from inside outward has 6. 6, 12, 24, 48, etc. tentacles, the innermost being the oldest and largest.

While sea anemones, hard (reef-building) corals (except *Millepora*), *Zoanthus* and black (or thorny) corals belong to the Zoantharia, the soft corals or dead men's fingers (or toes), organ-pipe coral, blue coral and horny corals (sea pens and sea fans) are included in Alcyonaria.

Sea anemones adhere to the sea bottom (mud or stones) by slime and muscle power, but can move 8 to 10 cm per hour by crawling. They may also move in a variety of other ways, e.g., by walking about inverted using the tips of their tentacles, somersaulting, reaching the sea surface and floating head downwards or inflating their body and rolling about in the waves.

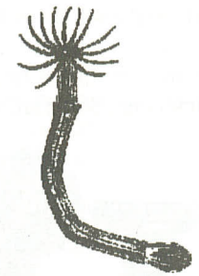


Fig.75 ***Edwardsia*** **sea anemone**

Multiplication (of the animal) is by division. In the primitive Gonactinian sea anemones, it is transverse, i.e. the top portion having the mouth and tentacles separates from the basal part. Others like *Sagartia* split vertically into two halves. Still other sea anemones multiply by pedal laceration; the pedal disc (base of the animal) puts out lobes which get constricted and are torn off as the animal moves. The torn edges unite, new tentacles develop, and soon complete little sea anemones are seen. If the sea anemone is cut, the basal part grows a new disc with tentacles, while the upper part remains as it is for a long time, though rarely it may grow new tentacles on the torn (lower) part. Some sea anemones may live for 50 years.

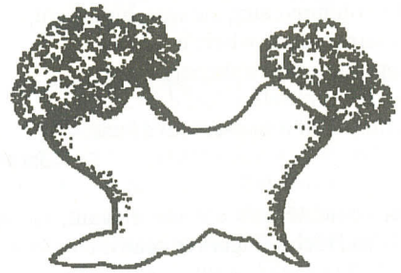


Fig.76 **A sea anemone dividing into two.(After Agassiz & Parker)**

Cerianthus is a cousin of sea anemones but can be distinguished by the different arrangement of its septa (partitions). It lives inside a tube made of a hardened slimy secretion in which are embedded shed stinging cells and sand grains. This tube may be up to a metre long, but the animal inside grows from a few to at most 35 cm. It can live for up to 40 years.

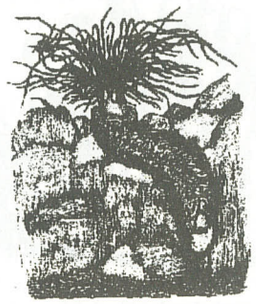


Fig.77 **Tube anemone (** ***Cerianthus*** **) inside its mucus tube (After Andres)**

Around sewage outfalls, where the sea water is diluted and at the same time rich in organic matter, you will find vast carpets of *Zoanthus*, which look like colonies of soft sea anemones connected together by a common fleshy base, with polyps of about a centimetre diameter shooting vertically up. Some are solitary.

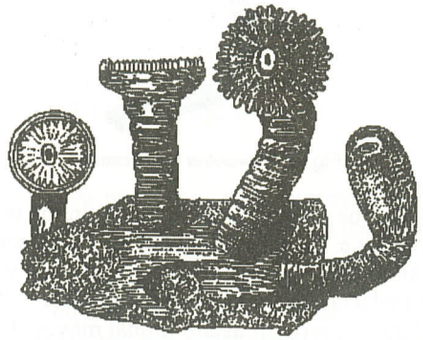


Fig.78 **Polyps of *Zoanthus* colony**

Whose tapering stems, robust or light,
Like columns catch the searching sight,
To claim remark where'er I roam,
Supporting each a shapely dome;
Like fair umbrellas, furl'd, or spread,
Display their many-colour'd head.

James Woodhouse

Other soft colonial coelenterates are the elegant, colourful soft corals, also called (rather disdainfully) dead men's fingers or dean men's toes.

Corals may be loosely compared to skeleton-building sea anemones living together in colonies. (A few, like *Fungia*, are solitary.) The unit of each coral colony is a tiny animal called a polyp. It has a hollow tubular body, on the top of which is the mouth surrounded by many tentacles. The polyps live together as a colony and secrete a cup-like skeleton made of lime (calcium carbonate) extracted from sea water. The wall of each cup is called a theca. There is no pedal disc and the tentacles are in whorls of six.

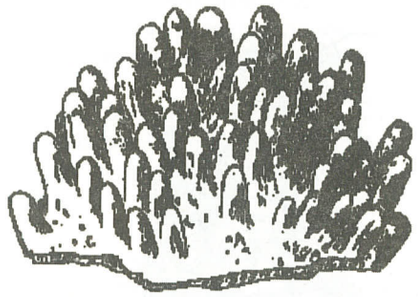


Fig.79 **Nullipore coral, showing blunt, finger- like structure**

When most people talk of corals, they are thinking of the reef-building or hermatypic corals. These require warm (23°-25° C), clear (free from silt), shallow (down to 30 m), brightly lit, undiluted (salt content not below 30 parts per thousand) water. They are restricted to a belt between 22° N and 22° S latitudes. In India, we have coral reefs in the Gulf of Kutch, Gulf of Mannar, the Andaman and Nicobar Islands as well as Lakshadweep Islands. The corals of the Andaman-Nicobar Islands cover a total stretch of 960 square kilometres, those of the Lakshadweep Islands 816 sq. km., Gulf of Kutch 460 sq. km., and Gulf of Mannar 94 sq. km. There are also ahermatypic (non-reef building) corals found even down to 8,000 metres.

The reef-building corals are restricted to shallow water as they harbour within their tissues minute one-celled algae (plants) called zooxanthellae. Each polyp has thousands of these, and they have never been found in the sea water outside a coral's body. The skeleton of Madreporarian (stony or true) corals is white; the polyps are mostly yellow, brown or green, and the beautiful hues of corals so appreciated by us are only in the live tissues and are due to the zooxanthellae. Under adverse conditions such as starvation or a rise in the temperature of the surrounding sea water, corals throw out their zooxanthellae and then appear bleached. Many corals, when exposed to ultraviolet light, glow in the dark, and the colour thus seen is different from their colour during the day.

The red coral (*Corallium rubrum*), though superficially resembling stony (madreporite) corals, is related to soft corals.

Most coral polyps are hermaphrodite, i.e., a polyp is both a male and a female.

The reproductive organs of corals are situated on the septa inside the polyps. Each polyp packs its eggs and/or sperms into a compact round mass, usually pink, but sometimes green or brown. A few days after full moon, in a phenomenon known as broadcast spawning, these are shot out into the water, all together, by thousands of polyps on a reef. Floating to the sea surface, they form streaks, and a couple of days later, the egg hatches into a larva called planula. This swims for a few days and then settles down at the sea bottom within a week, although it can swim about for up to three months if conditions are not suitable for settling. The planula crawls on the sea bottom until it finds a suitable spot, and then grows into a polyp. This polyp will then bud other polyps to start the future coral colony.

While the original polyp grows upwards, increasing in height, small individuals bud off from its sides. Here the original polyp forms the apex of the colony. In others, the apical polyp is the youngest, having budded off from an older polyp immediately beneath it. In brain corals (*Meandrina*), the division of the polyps is not complete; instead of the surface of the colony being studded with round pores containing the polyps, it is covered with meandering sinuous grooves fringed with septa, looking like the convolutions on the surface of our brain. In some cases, instead of budding, a polyp lengthens, the number of its tentacles and septa increases, and the polyp then splits into two– a process known as fission.

Artificial "reefs" have been made by dumping old tyres or motor cars into the sea, but their purpose is mainly to attract fish and tempt them to stay there, to be caught by anglers or fishermen. A novel approach to start new coral colonies is to place a steel frame in the sea and pass a weak electric current of 1 to 2 volts through it, the current

being generated locally by solar cells or wind/wave turbines. This frame acts as a cathode and makes the sea water around it slightly alkaline. (The anode which makes the sea water acidic is placed a couple of metres away from the steel frame.) The alkalinity causes calcium carbonate from the sea water to settle on the frame and form a limestone layer. This invites coral larvae to settle on it and grow to form new colonies.

The electric current also helps corals in another way. A live coral has to expend energy to create a slightly alkaline stream of water so that it can feed. By making the water alkaline, we give the coral a helping hand, as all its energy is now used to feed rather than be spent on creating an alkaline environment around it.

Corals have been found to grow 1 cm to 2 cm in a year on such steel frames. A higher voltage increases the rate of growth, but this results in limestone that is too soft.

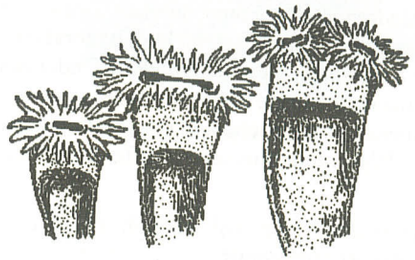


Fig.80 **Fission of coral polyp.**

Branching corals keep on dividing to form new branches; if broken off, a branch settling nearby will start a new colony. The branches may be short and stout, or long and slender, leaf-like, or flattened and plate-like. But only the surface is occupied by living tissue. Encrusting corals grow only on the edge of the colony. Plate corals also grow at the edges but lift off above the colony into the water.

Millions of millions thus, from age to age,
With simple skill and toil unwearable,
No moment and no movement unimproved,
Laid line on lineon terraced terrace spread,
To swell the heightening brightening gradual mound,
By marvellous structure climbing toward the day.
Each wrought alone, yet altogether wrought
Unconscious, not unworthy instruments,
By which a hand invisible was rearing
A new creation in the secret deep.
Omnipotence wrought in them, with them, by them;
Hence what Omnipotence alone could do,
I saw the living pile ascend,
The mausoleum of its architects,
Still dying upwards as their labours closed:
Slime the material, but the slime was turned
To adamant by their petrific touch:
Frail were their frames, ephemeral their lives,
Their masonry imperishable.

Montgomery *Pelican Island*

The rate of growth varies from species to species and from place to place. Branching corals have been known to grow from 25 to 50 mm per year. The slower growing massive forms may increase by as little as 5 mm per year. Actual measurements showed an increase from 76 cm to 188 cm in 23 years for a brain coral, and from 5.7 m to 6.85 m for *Porites*. A channel in a coral reef in the Andaman Islands which was 27 metres deep in 1887, was only 30 cm deep 37 years later.

Coral polyps are provided with stinging cells (nematocysts) which can shoot out a hollow thread containing venom. Corals with long tentacles feed with the help of these, but polyps with short tentacles secrete slime which entangle small food particles in the zooplankton to form mucous strands which are then wafted towards the mouth by ciliary currents. The polyps contract during daytime, but expand to feed at night.

When conditions are favourable, coral colonies may be overcrowded. In such cases, as with human societies, boundary disputes occur which are settled silently but mercilessly, at dead of night. Adjacent colonies of the same coral species just lay down a boundary wall of limestone between them– a "no man's land" to be crossed only at one's peril. Neighbouring colonies of different species resort to more aggressive warfare. Long filaments from the polyp's gut are shot out at night from the mouth or, sometimes from temporary openings in the polyp's body wall. They spread over the nearest polyps of the enemy and digest their tissues. The filaments are withdrawn back into the polyp at the crack of dawn, leaving behind a bare patch of dead coral some 10 mm across.

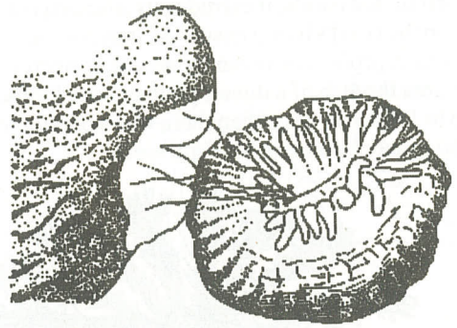


Fig.81

Coral warfare; the coral on the right has extended its mesenteric filaments onto the coral at left (After Lang)

Sometimes the corals under attack go on a counter-offensive. Over a period of time which may be weeks or even months, the victims develop specialised defensive tentacles, called sweeper tentacles, having bulbous tips loaded with stinging cells. These tentacles are longer than the mesenterial (gut) tentacles of the enemy, so that they keep the aggressor at bay and even cause the eventual retreat of the leading edge of the aggressor coral.

While corals may be able to face the unwelcome attentions of hostile corals, they may not be successful with a host of other enemies. Some sponges (*Cliona*) and date mussels (*Lithophaga*) bore into the corals by dissolving the limy skeleton by an acid secretion. The young of giant clams (*Tridacna*) burrow into the coral and pass their entire life here, enlarging the burrow as they grow. The long-spined sea urchin

(*Diadema*) makes tunnels some 7 cm deep and 3 cm in diameter and takes shelter at the bottom, and so do some worms.

Gall crabs live imprisoned in the cavities of branching coral. The female baby crab settles in a growing fork of coral branches and by constantly blowing water on it, causes the young branches to broaden and curve around the crab so as to leave a chamber in which it is permanently (but voluntarily) imprisoned.

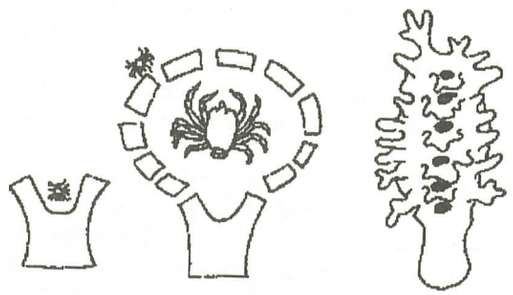


Fig.82 **Formation of gall by fusion of branches, caused by female gall-crab Complete gall on extreme right**

In the last three decades, a more sinister enemy has appeared on the scene. This is the crown-of-thorns starfish, named after the prickly spines that cover its six to 23 arms. Attaching itself to live corals, it extrudes its stomach out of its mouth and spreads its digestive juices on the coral's living tissue. As it moves on, it leaves behind a patch of dead coral which is then prone to erosion by waves or overgrowth of seaweeds. In six hours, it can eat an area the size of a dinner plate or over five square metres in a year. It was uncommon up to 1960, but since then there was a population explosion, and in four years it laid bare 360 square kilometres of coral reefs.

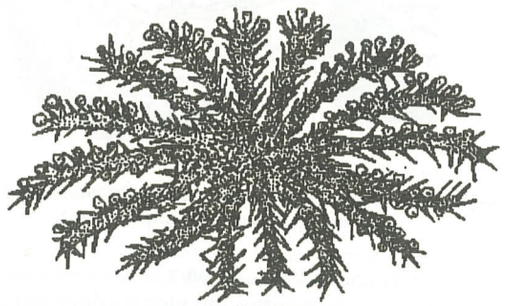


Fig.83 **Crown-of-thorns starfish, a cause of mass mortality in corals**

A tunicate *Didemnum* is also dangerous to live corals, using a serinolipid poison to kill them. It attaches to a coral and secretes the poison over it, leaving only a coral skeleton behind.

Coral reefs appeared as early as 225 million years ago; some existing reefs have grown continuously for the past 65 million years.

Some 600 species of corals are found in the Indian and Pacific Oceans, while there are about 100 species in the Caribbean region.

A coral reef has one of the richest ecological diversities (equalling or even exceeding that in an evergreen tropical forest), sheltering and providing food for a large variety of coralline algae (seaweeds which look somewhat like coral, as they too have hard calcium carbonate deposits in their tissues), Foraminifera, sponges, Millepora, called stinging or fire-coral but belonging to Hydrozoa, sea anemones, tube-dwelling worms, snails and clams, lobsters, prawns, crabs, mantis shrimp, starfish, sea cucumbers, sea urchins and a huge assortment of fishes. (Close to half of the world's marine fish varieties live on or near coral reefs, as do a large percentage of marine invertebrates.)

Mushroom corals (*Fungia*) are so called as they resemble the underside of a mushroom. They are solitary, and have large tentacles that look like worms when extended at night. They are quite mobile; they move on the sea bottom and can even right themselves if thrown upside down by a wave. Black corals (*Antipatharia*) are not true (madreporarian) corals but have a tree-like chitinous skeleton. The tentacles and septa are fewer– 6 to 24. When there are more than six tentacles, six of them are larger.

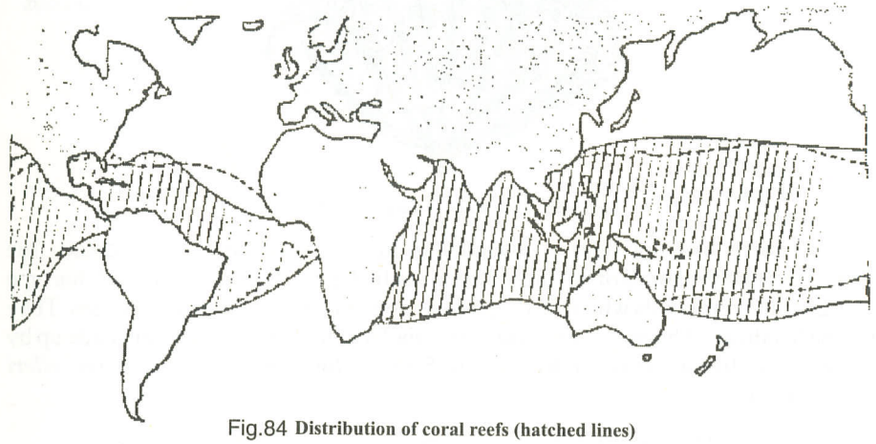


Fig.84 **Distribution of coral reefs (hatched lines)**

13 Deep-sea Corals

Unheard by them the roaring of the wind,
The elastic motion of the waves unfelt;
Still life is theirs, well-suited to themselves,
Nor yet unuseful.

When people think of corals, they imagine verdant tropical isles with clear, warm water in lagoons, vividly coloured corals and equally gorgeously hued fishes flitting among the coral branches. These are the reef-building or hermatypic corals. They are easy to see and admire because they live in shallow water. This is necessitated by the presence of one-celled algae (plants), called zooxanthellae, living in the tissues of the corals. These require sunlight for their photosynthesis, hence the corals are perforce restricted to shallow water where the light can reach them.

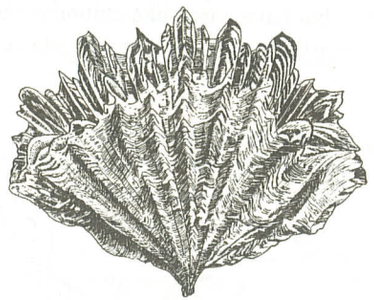


Fig.85 *Flabellum*. **A deep-sea coral**

If corals did not have zooxanthellae inside their bodies, they could free themselves from the bonds of having to live in sunlit depths. There are corals of this type called ahermatypic corals which do not harbour zooxanthellae within their bodies. They have the handicap of having a slow rate of metabolism, but this is more than made up by their ability to live at great depths down to 5,869 m for *Fungiacyanhus marenzelleri* found off Peru.

And far beneath the tempest's path
In coral grots defies the foe,
That never brake in heaviest wrath
The sabbath of the deep below.

J. Montgomery

They thrive even at temperatures of -1.1°C, but their rate of growth may be only one-fifth that of reef-building corals.

Most deep-sea corals, instead of forming a massive head with thousands of polyps, are solitary like sea anemones. The polyps rarely attain a size of 25 mm (diameter), and many are as tiny as a millimetre. But a few deep-sea corals form large, bushy colonies over a metre high.

A few deep-sea corals, like *Stephanocyanthus diadema*, have the typical hexameral (in six or multiples of six) symmetry, but most have hundreds of septa (partitions). As the young polyp grows, six septa are laid down. A little later, six more form, each between the septa of the first cycle (set), so that the polyp now has twelve septa. In the third cycle, 12 septa form between the earlier 12, and so on, doubling each time as the solitary polyp grows, until over 700 septa may be formed, producing a beautiful geometric design.

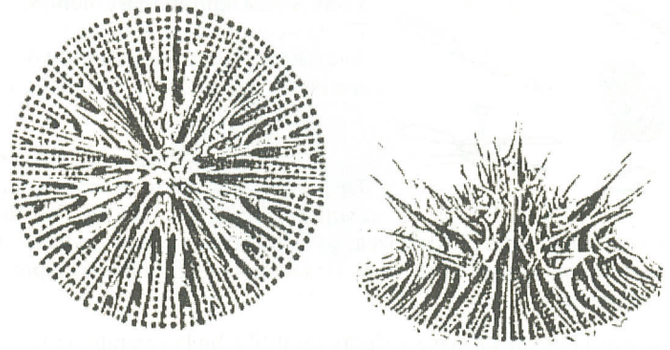
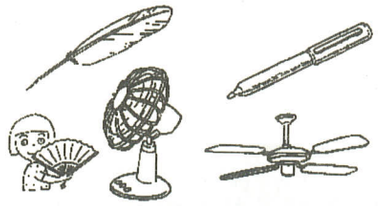


Fig.86 **One of the deepest known species of coral,** ***Leptopenus***

Some of the ahermatypic corals live in shallow seas, but they do not have zooxanthellae, and the colonial forms have fewer polyps.

14 A Miscellany of Home-use Items



There, with a light and easy motion,
The fan-coral sweeps through the clear, deep sea,
And the purple and scarlet tufts of ocean
Are bending like corn on the upland lea.

Percival.

We use writing pens, fans and jewellery. These items also occur in the sea, but in different *avatars*. They all belong to the sub-class Octocorallina or Alcyonaria of Anthozoa, so named because their tentacles and septa are eight or its multiples, instead of six as in Hexacorallina (Zoantharia) represented by sea anemones and corals.

Sea-pens (*Virgularia*) have a fleshy quill-like body resembling the feather quills used by our forbears for writing. (This was before the advent of fountain pens and, later, ball-point or felt-tip pens.) The body has a soft and long central axis, which is actually a single primary or axial polyp, along whose sides are a succession of flat, fleshy, leaf-like polyps. The central peduncle ends in a bulb with which it fastens to the substrate. The polyps are of two kinds– autozooids and siphonozooids; the latter have rudimentary or no tentacles and do not catch prey but drive a water current through the colony.

Fig.87 **Sea pen (*Pennatula*) (After Hyman)**

Sea-pens grow from a few to 50 cm long and, if disturbed, burrow rapidly into the mud. They are often prettily coloured– yellow, orange, red and purple being common. Many are bioluminescent, i.e., they give out their own light and shine with a blue or violet glow at night. When disturbed at one end, a wave of phosphorescence passes along the colony to the other end just like a blush.

Cousins of sea-pens are the powder-puff (*Cavernularia*), a stout, radially symmetrical cylinder over whose surface are scattered the polyps. The sea pansy (*Renilla*) is similar but has a spherical body strewn all over with polyps.

Sea-fans (*Gorgonium*) and sea-whips are also related to sea-pens. In the former, the fan-like body branches out in one plane and, though not as hard as corals, has a skeleton of a horny consistency made of gorgonin, a protein similar to the keratin of our hair and finger-nails and reptilian scales. (Today's generation, used to electric ceiling, table and pedestal fans, are not familiar with the hand-held fans, made of palm leaf or stiff cardboard, used in the first half of the 20th century.) Strewn all along the skeleton are numerous polyps. The plane of a sea-fan is at right angles to the water current, so that they can have the maximum surface area exposed to the current for the polyps to capture food particles and plankton drifting in the current. In some sea-fans, the main branches are united by numerous cross-connections to form a beautiful lattice or sieve-like fan.

Fig.88
Powder- puff or sea pansy (*Renila*). (After Hyman)

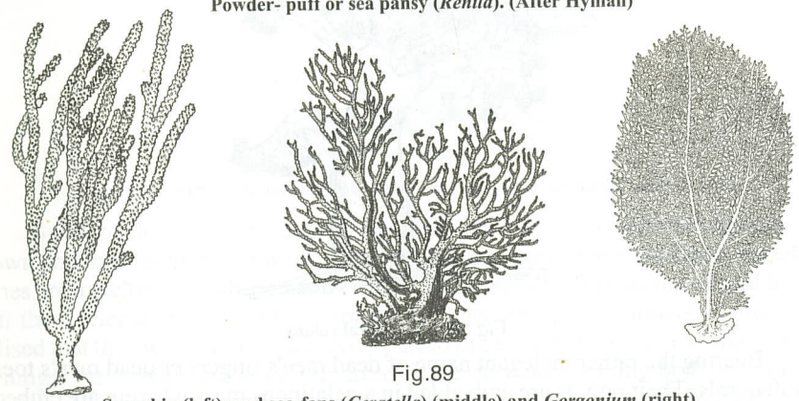


Fig.89
Sea whip (left), and sea-fans (*Ceratella*) (middle) and *Gorgonium* (right) (After Hyman, Spencer and Hyman respectively)

Sea-fans are also brightly coloured yellow, pink, orange, red, purple and even white. They often grow on vast stretches of the sea bottom to form veritable submarine gardens. Some sea-fans may be as much as 2 to 3 metres across. Twined around their branches are admirably camouflaged tiny brittle stars of the same colour, and the cowry-like snail, *Ovulum*, also lives on them. Elongated gorgonids with only one stem or a few branches are called sea-whips.

Red coral is actually a Gorgonacean and grows in the Mediterranean Sea and off Japan at depths of 30 to 200 metres. It is used as setting in amulets and necklaces.

Sailor, come ashore,
"What have you brought me?"
"Red coral, white coral,
Coral from the sea.
I did not dig it from the ground,
Nor pluck it from a tree;
Feeble insects made it
In the stormy sea."

Christina Rossetti

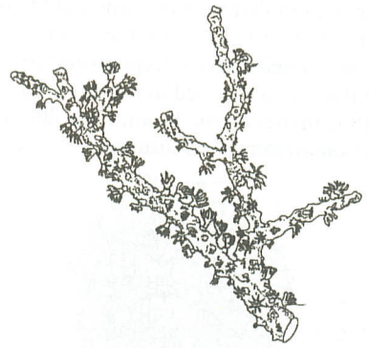


Fig.90
Red coral (Corallium rubrum). (After Hyman)

Fig.91 **A soft coral colony**

Bearing the rather inelegant name of dead men's fingers or dead men's toes are the soft corals. Their polyps are embedded in a gelatinous mass wherein are embedded isolated calcareous spicules. The colonies often have bright colours.

The blue coral (*Heliopora*) has a massive calcareous skeleton, composed not of spicules but of crystalline fibres made of aragonite fused into lamellae (plates). The polyps are brown. The blue colour of their skeleton is due to iron salts.

Fig.92 **Piece of organ pipe coral (*Tubipora musica*), showing partitions**

The organ-pipe coral (*Tubipora musica*) colony has parallel, upright, closely set, vertical tubes united at regular intervals by horizontal platforms. Unlike true corals where the skeleton is white, *Tubipora*'s skeleton has a maroon colour due to iron salts.

15 Psst! It's time someone noticed us too

(Variations in a theme)

Involved in a sea-wrack, here you see a race
Which, Science, doubting, knows not where to place;
On shell or stone is stopp'd the embryo seed,
And quickly vegetates a vital breed.

George Crabbe

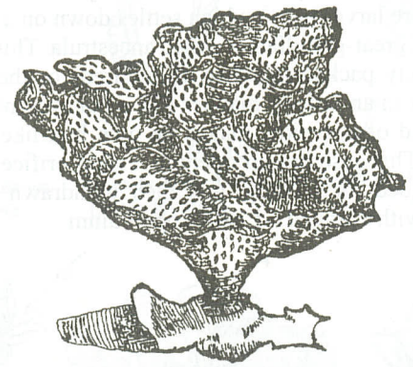


Fig.93 **Rondelet's illustration of a polyzoan ectoproct made in 1558**

Some of the commonest and most abundant marine growths are also the least known and most confusing forms. These are the sea-mats or moss-animals. Even their names are a welter of confusion and change. Being sessile, they were clubbed together with the coelenterate hydroids as zoophytes (meaning plant-animals). Later, it was realised that they were more highly evolved, having a distinct digestive system with two openings, viz. mouth and anus. (Hydroids have only one, serving both as mouth and anus.) In 1830, Thompson distinguished the higher forms from the hydroid polyps, calling them Polyzoa. Around the same time (1831-1833), Ehrenberg independently noted the two openings and named such animals as Bryozoa. English biologists preferred to use the term Polyzoa, while continentals (i.e. European) and Americans used Bryozoa. To compound the confusion, other scientists lumped the moss-animals with lamp-shells (Brachiopoda) into the phylum Prosopygia, while yet others consider a major portion of Polyzoa, viz. the Ectoprocta, together with lamp-shells and Phoronid "worms" into a phylum Tentaculata, first suggested by Hatschel in 1888. This grouping left out the other big group of Polyzoa, viz. the Entoprocta.

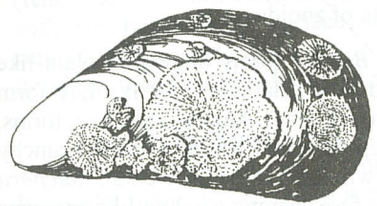


Fig.94
Encrusting Polyzoan colonies on a mussel shell. (After Rogick)

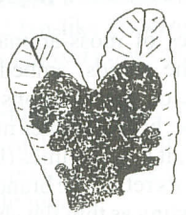


Fig.95
***Acanthodesia* colony on an algal frond. (After Hyman)**

Fig.96
Colony of *Hornera*. (After Calvet)

Moss-animals form colonies on rocks, shells, seaweeds and submerged structures like wharf piles and jetties, in the form of encrustations or sometimes as tiny erect bushy forms, as in *Bugula* and *Hornera*. A few moss-animals burrow into the shells of living or dead snails or barnacles. *Hypophorella* lives between the layers of the tubes of tube-dwelling worms *Terebella* and *Chaetopterus*. The zooids project into the lumen of the tube, where they are bathed by the water currents made by the worm. *Harmeriella* kills the polypides of the moss-animal *Tubiporella*. Others live on legs and even the gills of crabs. In general, they do not withstand desiccation very well, hence they are found beyond low tide limits, except in rock pools that hold water even at ebb tide. A few moss-animals are soft, but most have a horny appearance due to a "shell" of chitin, while others have a limy shell. Each colony, called zoarium, is started by a swimming trochophore larva (baby) which settles down on a substratum to change its shape and become the great-grandfather called ancestrula. This buds off progeny, called zooids, that are closely packed together in hundreds or thousands, and are closely attached back to back in an orderly manner like a honeycomb. Each individual of the colony, called a zooid or polypide, makes its own box-like house or case, called a zooecium or cystid. This case has an opening, called orifice, from which part of the animal can be extended for feeding, and then withdrawn inside. This opening is sometimes provided with a hinged lid, called operculum.

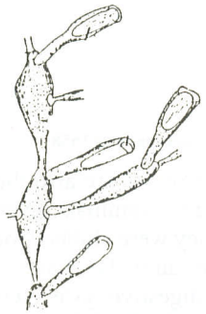


Fig.97

Part of colony of *Aetea* (After Marcus)

Fig.98

Zooids in pairs along creeping stolon of *Aeverrillia* (After Rogick & Croasdale)

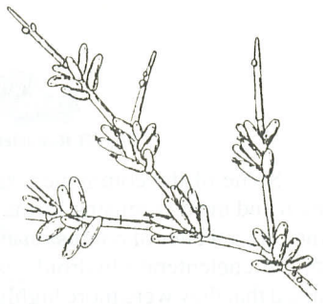


Fig.99

Clustered zooids on erect stolons of *Bowerbankia.* (After Marcus)

The colony is sometimes partly erect and partly clinging to the substratum. The animals, borne on erect or creeping stolons, may be single (as in *Aetea*), in pairs (as in *Aeverriliea*), in clusters (*Bowerbankia*) or in irregular rows (*Vesicularia*). In *Amathia*, the animals are in double rows arranged in spirals. The stolons are tubes of the body wall divided by perforated partitions (also called nodes or septa). In between two nodes is the internode. In *Cothurnicella* (formerly *Chlidonia*), each internode of the branches gives rise to a single file of zooids.

In the creeping types of moss-animals, *Bugula* forms branching plant-like growths. In *Alcyonidium*, the zooids, embedded in a gelatinous matrix, may form upright cylindrical growths or encrustations on sea-fans. Among calcified forms, *Flustra* acquires a leafy shape, but resembles millepore corals, having a brittle, crunchy consistency of potato wafers; it is sometimes (but wrongly) called lace-coral. *Retepora* has a lace-like appearance as its reticulate branches fuse, leaving window-like openings (fenestrae). The forms encrusting as thin flat sheets are made up of one layer of animals with their backs (dorsal surface) cemented to the substratum, either radiating from a

central point (as in *Cryptosula*), spread fan-like (*Schizoporella*) or taking the shape of the substratum (*Acanthodesia*). *Membranipora* grows as encrustations on seaweeds.

Fig.100

Irregularly positioned zooids on a erect stolons of *Vesicularia* (After Busk)

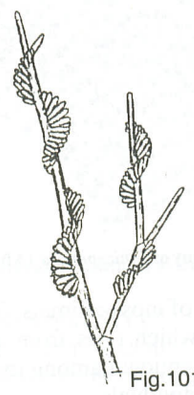


Fig.101

Spirally placed zooids of *Amathia* (After Hyman)

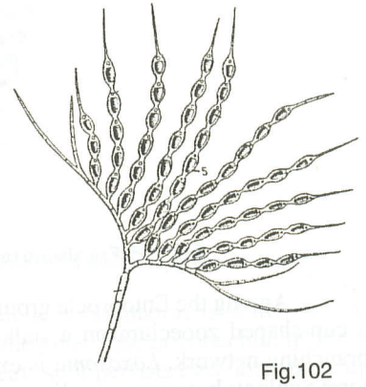


Fig.102

Branches with zooids in row, in *Cothurnicella* (After Levinsen)

Fig.103

Branching colony of *Bugula* (After Hyman)

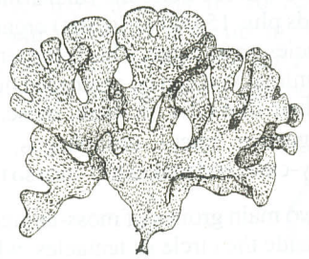


Fig.104

Calcified colony of *Flustra* resembling a millepore coral (After Hyman)

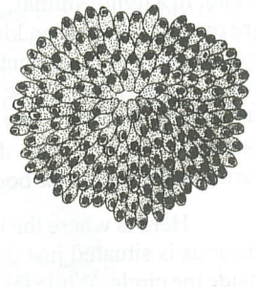


Fig.105

Radiating colony of *Cryptosula* (After Hyman)

In the creeping types of moss-animals, *Bugula* forms branching plant-like growths. In *Alcyonidium*, the zooids, embedded in a gelatinous matrix, may form upright cylindrical growths or encrustations on sea-fans. Among calcified forms, *Flustra* acquires a leafy shape, but resembles millepore corals, having a brittle, crunchy consistency of potato wafers; it is sometimes (but wrongly) called lace-coral. *Retepora* has a lace-like appearance as its reticulate branches fuse, leaving window-like openings (fenestrae). The forms encrusting as thin flat sheets are made up of one layer of animals with their backs (dorsal surface) cemented to the substratum, either radiating from a central point (as in *Cryptosula*), spread fan-like (*Schizoporella*) or taking the shape of the substratum (*Acanthodesia*). *Membranipora* grows as encrustations on seaweeds.

Among the Entoprocta group of moss-animals, *Barentsia* and *Pedicellina* have a cup-shaped zooecium on a stalk which rises from a horizontal stolon forming a branching network. *Loxosoma* is exceptional among moss-animals in that it does not form a colony, but grows as solitary individuals.

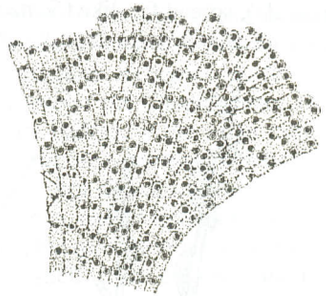


Fig.106 **Fan shaped colony of *Schizoporella* (After Hyman)**

Among the Entoprocta group of moss-animals, *Barentsia* and *Pedicellina* have a cup-shaped zooecium on a stalk which rises from a horizontal stolon forming a branching network. *Loxosoma* is exceptional among moss-animals in that it does not form a colony, but grows as solitary individuals.

The beauty of a colony of moss-animals lies in the symmetrical repetition of the individual cases. But it requires a microscope to discern the individual animal, the zooid. In a living animal, you will see a circular (in marine moss-animal, of which there are over 4,000 existing kinds plus 15,000 as fossils) organ encircling the mouth, with a row of many (8 to 34) tentacles on its ridge. This is the tentacular crown or lophophore, and is the only part of the animal that can be protruded out of the orifice. The tentacles are hollow and have tiny hair-like cilia on them; these, by their beats, form a food-catching funnel. The digestive tract– oesophagus, stomach and intestine are permanently inside the body-case, and makes a U-turn so that the anus is near the mouth.

Here is where the two main groups of moss-animals diverge. In the Ectoprocta, the anus is situated just outside the circle of tentacles, while in Entoprocta the anus is inside the circle. While the tentacles in Ectoprocta can be completely withdrawn into the body cavity, in Entoprocta the tentacles are rolled inside a cup-like hollow within the lophophore called vestibule and then partly covered by a fold of membrane.

Moss-animals differ from the more lowly evolved hydroids in having cilia-bearing tentacles and a separate digestive tract. Compared to the vast numbers of varieties of marine ectoprocts, there are very few freshwater forms, living under stones or on twigs in lakes, ponds and streams. These have an oval or horseshoe-shaped lophophore.

In addition to the typical zooid described above, many moss-animals also have two kinds of modified zooids. One is the avicularium, looking very much like a miniature bird's head complete with a beak which opens and closes; some of these are mounted on a stalk which can bend and stretch. The avicularia are used to capture tiny organisms that chance to roam on the sea-mat colony, and also to prevent the larvae of other moss-animals from settling on a colony and then growing over it. The beak or mandible of an avicularium is only the modified operculum of the zooid.

Another kind of modified zooid are the vibracula. Here the operculum is modified into long bristles, or setae, movable in all directions. These are used to sweep away debris or larvae settling on the colony.

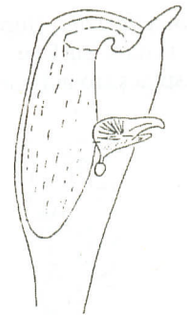


Fig.107 **Zoecium of *Bugula*, showing a avicularium (on middle right).(After Hyman)**

While the regular repetitive symmetry of a colony is fascinating to watch with a magnifying glass, so also is each zooecium. The outer case or zooecium inside which the living animal withdraws is resistant to decay, so it persists even after the animal's death. It is this part that is used for identifying different kinds of moss-animals; in fact, specialists of moss-animals burn away the soft parts with a blowpipe so as to see the hard parts more clearly.

In the most primitive moss-animals, the zooecium is a thin, horny (chitinous) tube- or vase-shaped box with the orifice at the tip. In *Aeverrillia*, the terminal orifice is surrounded by long spines around it. In *Farrella* and *Frustrelliadra* (= *Flustrella*), the orifice has two lips, the lower one of which can be closed– the beginning of the formation of operculum.

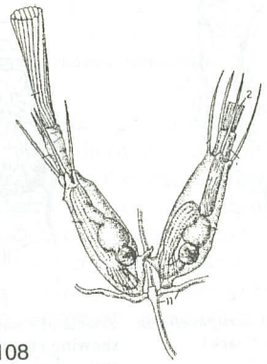


Fig.108
Zooids of *Aeverrillia*, showing spiny zoecia (After Marcus)

Fig.109
Top part of zooid of *Farrella*, showing closing lips (After Van Beneden)

In the compact moss-animals, the oval, rectangular or polygonal zooecia are arranged close to each other, and the orifice shifts from the tip to a subterminal position. The back (i.e. dorsal surface) of the zooecium is attached to the substratum, and the orifice is on the ventral or frontal face. Extension and withdrawal of the lophophore changes the volume of the zooid, which has to expand to accommodate the withdrawn lophophore. The zooecium may be strengthened by its walls becoming thicker everywhere except for a ventral area of thin cuticle called the frontal membrane. When this frontal membrane is removed, the large opening on the ventral surface is called an opesium. The frontal membrane may occupy the entire ventral surface of the zooid

as in *Beania*. In *Bugula* and *Bicellariella* (formerly *Bicellaria*), the thickening encroaches considerably on the ventral surface. As the thin frontal membrane is vulnerable, it is often protected by spines around it, as in *Beania* and *Bicellariella*.

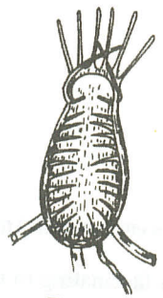


Fig.110
Zooids of *Beania*, showing spines around frontal membrane (After Hyman)

Fig.111
Zoecium of *Bicellariella*, showing very long spines (After Hincks)

The walls of the zooecium may be further thickened by deposition of lime (calcium carbonate) on the underside of the chitinous cuticle. Here too the frontal membrane may be protected by a row of spines or a few large spines as in *Electra*. In *Scrupocellaria* a spine of bizarre shape, called scutum, protects the frontal membrane. Sometimes, as in *Conopeum*, the frontal membrane itself produces small chitinous spines.

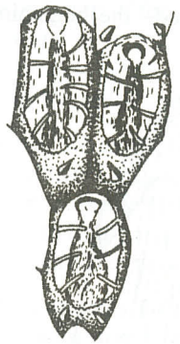


Fig.112
Zoecium of *Electra*, showing calcified border (gymnocyst) of frontal membrane which is protected by calcified spines (After Marcus)

Fig.113
Zooids of *Scrupocellaria* (After Peach)

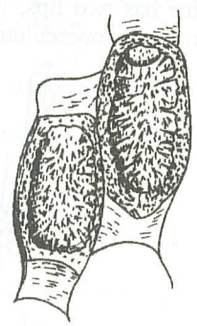
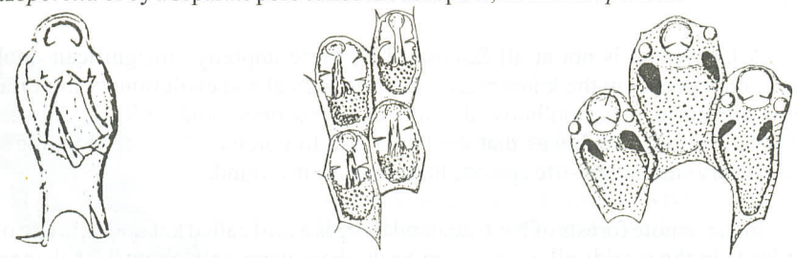


Fig.114
Zoecia of *Conopeum*, showing chitinous spines on frontal membrane (After Marcus)

In other, more complicated forms of zooecia, the rows of calcified spines arch over the frontal membrane and fuse to form a calcareous shield outside (i.e. ventral to) the frontal membrane. In yet others, a calcareous shield called the cryptocyst, grows from the rear to the front edge, from the least developed as in *Electra*, through half developed in *Acanthodesia*, to almost complete, leaving two large holes or opesiules in *Thalamoporella*. Inn *Smittina*, the cryptoocyst is complete, lealving areoles (holes) around the border. In *Colletosia*, it is in the form of ribs, with rows of holes between the ribs.

When the zooecium is completely calcified, the zooid would not be able to expand or contract, were it not for a mechamism in the form of a thin-walled sac (called

the compensation sac or ascus) immediately beneath the calcified front. The ascus opens to the outside by a notch called sinus or vanna in the proximal rim of the orifice as in *Schizoporella* or by a separate pore called the ascopore, as in *Microporella*.



(A) (B) (C)

Fig.115 **Stages in development of cryptocyst (dotted), least in (A) *Electra*, through (B) *Acanthodesia* to (C) *Thalamoporella* (After Marcus)**

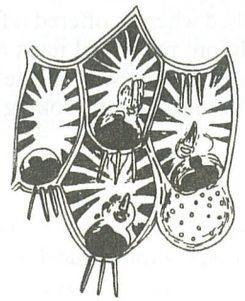


Fig.116
Zoecium of *Schizoporella*, showing sinus notch (After Marcus)

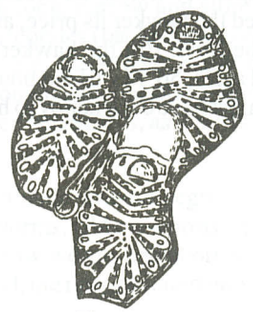


Fig.117
Zoecium of *Microporella*, showing ascopore (After Marcus)

In addition to budding—an asexual proces, sexual reproduction also exists in moss-animals. These may be hermaphrodite or have separate sexes. The eggs in a few moss-animals are released into the sea, but most have brood chambers inside which the eggs develop. These hatch as trochophore larvae which swim in the plankton before settling down as ancestrula. Budding may be slow or fast; *Membranipora* showed 10,000 zooids in three weeks, while *Schizoporella* had only 25 zooids in one month, increasing to 400–500 in two months and a whopping 30,000 in five months. Individuals in a colony regularly degenerate to form a brown body, and then regenerate.

Fig.118
***Hippothoa* colony,showing male bottom), sterile (at bottom right) female (globular,with spots) (After Marcus)**

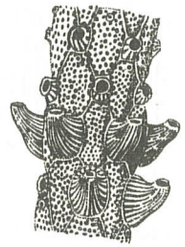


Fig.119
***Tubucellaria*, showing orificial collars used as brood chambers (After Marcus)**

Fig.120
***Hornera* colony, showing (at gono zooid (swollen, at left) and acting as brood chamberzooids (After Calvet)**

Moss-animals would not seem to be very nourishing, but they are eaten by flatworms, sea urchins, sea cucumbers, small polychaete worms, some snails and fishes.

A lay person is not at all fascinated by these unpretty insignificant-looking animals; only people in the know realise their biological and evolutionary importance. We have all read in our schoolbooks the story of a horse being sold for Rs. 2, and a cat for Rs. 2,000. The only hitch was that the buyer had to purchase both of them together. There is a very similar real-life episode that comes to my mind.

In the remote forests of New Zealand there is a bird called kakapo. It is one of the rarest birds in the world; till a few years back, there were only about 14 kakapos left alive, and it is still on the verge of extinction. An old-goods hawker, selling his wares from door to door, had a stuffed and mounted pretty looking duck, as well as a dusty stuffed kakapo. My friend, an ornithologist and hence well knowing the rarity of the kakapo, asked the hawker its price, and was astonished when he offered it for Rs. 5. He jumped at the offer. But the hawker had one condition; my friend must also buy the duck, priced at Rs. 50. My friend bought both the birds and threw away the duck, while the hawker must have been happy to have got rid of the big ungainly looking bird!

16 "Worms" that are *not* worms

With his rivals he next had to strive,
To woo him a mate and a thrall;
So the handsomest managed to wive
While the ugliest went to the wall.

A ballad of evolution

From the early days of natural history, people have tended to call anything long, narrow and slimy as a worm. Even the great taxonomist Linnaeus put most invertebrates (backboneless animals) into the single group Vermes (worms). True worms are those with many rings on the exterior; these rings mark the position of partitions inside the body, dividing it into innumerable segments. Familiar to all of us are the earthworms, as well as their marine cousins, the polychaete or bristle-footed worms.

There are also many diverse groups of animals without segments, which are lumped together as "worms". Thus we have flatworms, ribbon worms, spoon worms, peanut worms, beard worms, Phoronid worms, arrow worms and acorn worms. While the first two have relatives in fresh water and on land, the rest are found only in the sea.

When people think of flatworms, the usual response is "Ugh! How ugly!", for they are reminded of the horrible tapeworms, thread worms and liver flukes which live as parasites inside our body. Yet some marine, free-living flatworms are some of the most colourful denizens of the sea.

Flatworms are soft, transparent, inconspicuous, leaf-like animals usually 25 to 40 mm long. A coating of tiny, constantly vibrating short hairs (cilia) enables them to glide over the sea bottom, but they can also swim with a flapping or rippling (as in sting rays) motion. It is the tropical flatworms which are as colourful as nudibranchs (sea slugs).

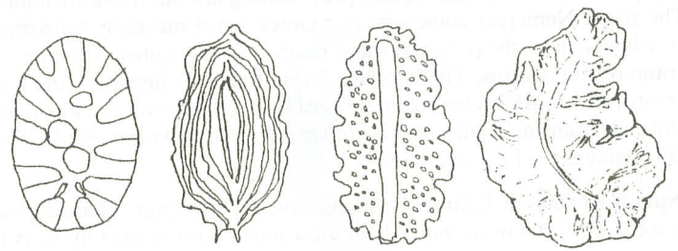


Fig.121 **Varieties of flat worms**

Two eye-spots help the worm to see. Oxygen for breathing is absorbed through the skin, there being no gills. The highly branched intestine has no anus, undigested food being thrown out of the mouth. Each individual has both sexes, so that any two can come together and mate. In some, there is no female sexual opening, so that the male organ punctures the body of the female anywhere and fertilises her eggs.

Flatworms feed on wheel-animalcules (rotifers), round worms (nematodes), tiny crustaceans and segmented worms; larger flatworms can devour barnacles, oysters, sponges, sea slugs and sea squirts, and are even cannibals on other flatworms. They cover their prey with a thick layer of slime to immobilise it. Even large prey like moon snails can be thus eaten.

Flatworms belong to the class Turbellaria of the Platyhelminthes and to the order Polycladida, which is entirely marine.

Sea bathers' itch is caused by the larvae, called cercaria, of another class of the Platyhelminthes called trematodes. The adults are normally parasites of marine birds. The larvae burrow into our skin, causing irritation and inflammation. However, the biochemistry of our body is not compatible to their continued development, so that they soon die. They attack parts of the body which remain wet with sea water for longer periods than uncovered skin, like inside swim trunks. A prompt shower with fresh water will kill them. The rash does not persist for more than a few days and is not harmful.

Ribbon worms (*Nemertea*) are, as the name implies, long like a ribbon, found under stones where there is mud or sand, and lie coiled in a knot. They have remarkable powers of lengthening and shortening. One or several pairs of eye-spots enable them to see. Although the body is not segmented externally, the internal organs tend to repeat themselves, as if foreshadowing the segmented appearance of true (polychaete) worms. Sexes are usually separate.

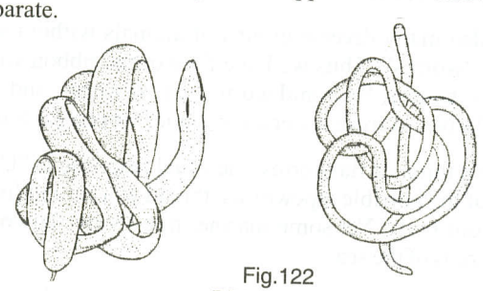


Fig.122
Ribbon worms

A hallmark of ribbon worms is the proboscis (snout), which normally lies inside the front end of the worm but can be extended inside out, like the finger of a rubber glove, to shoot out beyond the mouth and capture prey, coiling around it and then pulling it to the mouth. The name Nemertea comes from a Greek word meaning "unerring", since the proboscis, which can be thrust out quickly, never misses its prey. The prey may be quite large shrimp or true worms. The bootlace-worm pokes its head into the tube of a tube-dwelling worm and swallows the worm by getting its mouth over the worm just as a snake does. Its gut ends in an anus. They may be dull in colour or strikingly gaudy. Though usually small (2 cm), some are as long as 25 metres.

Spoon worms, or **Echiurid worms** have a long, spoon-shaped extension like a proboscis at the front end of the body. Its hollow lower portion has tiny hairs (cilia) which sweep tiny organisms into the mouth. They live in sand and mud or among stones in shallow water. They may be as small as 3 cm or quite big– 30 cm, excluding the 8-cm long proboscis.

Peanut worms, e.g. *Dendrostomum*, have a characteristic introvert which can be pulled into the body, again like the finger of a rubber glove. The body, when contracted, looks somewhat like a peanut, as the introvert is now inside the trunk.

When extended, the mouth can be seen at its tip, surrounded by tentacles. The looped intestine is twisted spirally, so that the anus is located midway on the introvert. They live in cracks of rocks or in sand or gravel under stones. They feed, like earthworms on land, by swallowing mud or sand from which the nutrients are extracted.

Fig 123 **Spoon worms**

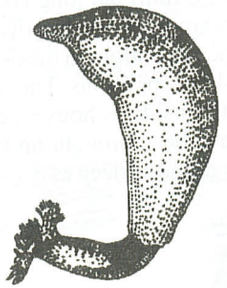


Fig.124 **Peanut worm**

Sipunculid worms (to which peanut worms also belong) have the body surface having square or rectangular patterns due to the circular and longitudinal muscles below the skin. Their introvert is not as long as in the peanut worms.

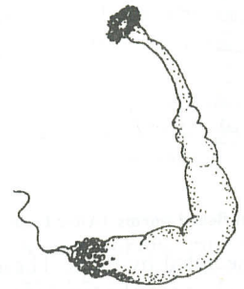


Fig.125

Fig.126
Sipunculid worms

Priapulid worms have no tentacles, while the trunk has horizontal wrinkles. The thick proboscis is covered with spines, while the hind (tail) portion is covered with papillae which help in breathing.

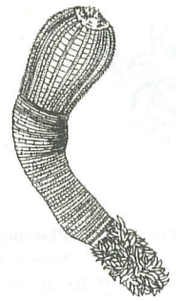


Fig.127
Priapulid worm

Spoon worms, peanut worms, sipunculids and priapulids are grouped together among Gephyrea, and their common characteristic is a larva (baby) shaped like a spinning top and called a trochophore.

Beard worms or Pogonophores (from the Greek word *pogon*, meaning beard) are extremely thin (½ to 2½ mm) but long (10 to 35 cm) worm-like creatures without mouth, gut or anus. There are from one spirally coiled to as many as 200 tentacles at the front end. They live on the sea bottom in tubes secreted by them, which may be smooth or have ringed or funnel-like repetitions. The tubes are much longer than the animal, so that it can shuttle to and fro inside its house. Sexes are separate. You will not find them on the seashore. They have been brought up from depths of 125 to 3,500 metres; one species, though normally found as deep as 8,100 metres, has been dredged from as little as 23 metres.

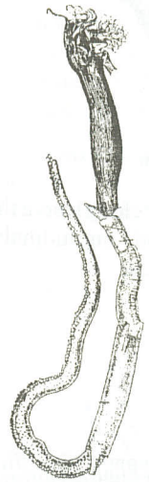


Fig.128 **Beard worm (After Ivanov)**

Fig.129 **Tube of Beard worms (After Ivanov)**

Phoronid worms also live in chitinous tubes secreted by them. These tubes may occur singly, partially buried vertically in sand or mud, or may be tangled together. They are found to occur down to 50 metres. The tubes gather sand grains, shell fragments and even small pebbles.

Fig.130
A cluster of phoronid worms (After Shipley)

Fig.131
Phoronid worms inside tubes lined with sand grains and shell fragments (After Shipley)

The thick-set body has a mouth leading to an enlarged stomach, continuing to the intestine which runs to the hind end and then loops to end in an anus near the mouth. Characteristic of all Phoronids is the crown of tentacles, called lophophore, consisting of a single row of tentacles borne on a double ridge and curved into a crescentic shape.

The number of tentacles may vary from 18 to as many as 300. Most phoronids do not exceed a length of 10 cm, but some are double this length, while other tiny ones are only 5 mm long.

Arrow worms, also known as glass worms or Chaetognaths (meaning spiny-jawed) do not have the sinuous flexibility and long body which we associate with worms. They are transparent, quite rigid, dart-like animals from 1 to 5 cm long, found drifting among plankton. (Some in the Antarctic seas grow to a whopping 20 cm.)

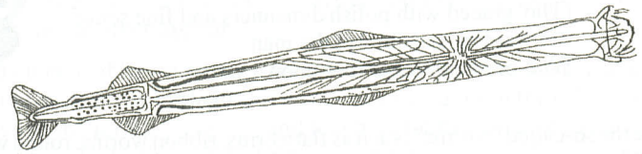


Fig.132 **Arrow worm**

The body has two pairs of horizontal fins which act as stabilisers, and ends in a spade-shaped tail fin. The head is provided with a set of long, sharp, recurved spines, often called jaws, which are normally covered inside a fold of skin. When it sights its prey with the help of two tiny eye-spots on the head, the skin folds back and the spines fan out on either side of the head to skewer the struggling prey. Two rows of teeth on the underside of the head now come into play. It is believed that the prey is detected by many fine hairs on the body which are sensitive to vibrations of the water made in the vicinity of the prey, mainly copepods.

Arrow worm (*Sagitta*) are hermaphrodites, with both sexes in an individual. The paired ovaries are situated in the middle region of the body on either side of the gut, while the testes lie farther back in the tail. The tiny 1 mm long babies are also carnivorous.

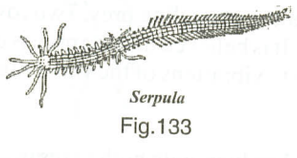
Acorn worms, unlike the primitive creatures described above, are high up on the ladder of evolution. In fact, they are the progenitors of fishes, and are described elsewhere. (See the chapter "Our forefathers".)

17 Legs, Fuzzy-wuzzy Creepy Crawlies of the Sea

I would not enter on my list of friends
(Tho' graced with polish'd manners and fine sense,
Yet wanting sensibility) the man
Who needlessly sets foot upon a worm.
Cowper

Unlike the so-called "worms" (such as flatworms, ribbon worms, round worms), the true or Annelid worms have their body consisting of a series of similar, repeated divisions (metameres or segments) by cross-partitions or septa. Each ring of the body of the marine annelids (the Polychaeta) has a pair of flaps called parapoda (false feet), divided into parts and provided with bundles of many bristles (setae); these are used as paddles for swimming. There is a distinct head with eyes and tentacles.

Fig.134
Nereis *Nephthys*



Serpula
Fig.133

Polychaete worms can be divided into two main groups- (1) the Errantia or wanderers, and (2) the tube-dwelling Sedenteria (sedentary worms). Typical swimming polychaetes are the red cat-worms (*Nereis*) and rock-worms (*Marphysa*), found burrowing in mud banks and dug out by anglers for bait. The body is long, slender and with segments throughout its length. Each segment bears laterally a pair of swimming parapodia. The prostomium (front of head) carries four eyes and two tentacles (also called antennae). The second joint, or peristomium, is perforated by the mouth, and has two pairs of tentacles (called tentacular cirri) on either side. They also have a pair of horizontally moving jaws which can give a painful nip if handled carelessly.

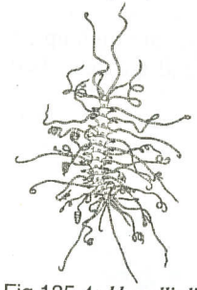


Fig.135 *Amblyosyllis lineata*

The worms are muddy brown in colour and grow to 30-40 cm. Some nereid worms are found living in sea shells occupied by hermit crabs; they can be seen sharing the hermit crab's meal. Catworms can be easily collected by inverting a tin on the mud and stamping it down. The air in the tin, as it gets compressed when the tin is suddenly forced down, frightens the worm which jumps out of its burrow.

A worm to be handled with caution is *Eurythoe*. It is rather short (6 to 7 cm), with a salmon-pink body fringed with long white setae, and lives under stones. If the worm is handled, the bristles penetrate the fingers, break off and hurt like glass splinters. Another worm to be avoided is the 25 cm long fire worm (*Chloeia*). It frequently swims in the sea, hence its body is thick and muscular. Although it is not believed to secrete a poison, puncture wounds from its spines become intensely inflamed and usually become badly infected.

Fig.136 **Scale worm**

In the scale worm (*Polynoe*), a small worm hardly 3 cm long, the back is covered by two rows of flat plates or scales, called elytra, like overlapping tiles on a roof. The elytra are shed at the slightest disturbance.

Fig.137
Sea Mouse

The sea-mouse (*Aphrodite*) too has a series of elytra, but these are hidden under a soft felt-like layer of mouse-grey colour. It does not look like a typical worm; the body is broadly oval, up to 30 cm long. On the parapodia are long stout bristles, and a veritable armour of iridescent tufts of prickly bristles and compound hairs on its sides flash like a rainbow.

It seems the humble sea mouse (*Aphrodite*) has stolen a march over scientists who invented a photonic crystal in 1991. (Such a crystal traps and controls photons the elementary 'packages" of light.) Its spines normally appear deep red in colour. But when light falls on a spine perpendicular to its axis, stripes of blue and green appear.

The advantage of having many feet was brought home to me at a marriage. The bride's brother as well as the bridegroom were our colleagues in the office, but only the former had invited me for the reception and lunch thereafter. Four of us had some work later in the day, so we had informed the bride's brother that we would grace the reception but would not stay for lunch.

At the hall, however, the groom insisted on our staying for lunch, and would not take 'No' for an answer. We tried to slink out and escape, but were accosted by the groom. We gave an excuse that the hall was stuffy, so we wanted some fresh air outside. Just opposite the hall was a bus terminus, and there was open ground all around. We planned to take a circuitous route in the fields, come back unnoticed to the bus stop and take a bus to the railway station. But the groom must have smelt a rat, as he was standing on the verandah and looking at us all the time. The only hiding place was a small temple, so we made our way there, hid behind it and looked for a chance to go to the bus stop.

The groom was still peering intently at the temple. Fortunately for us, there was a ditch by the side of the temple which ran all the way up to the bus stop. It was only waist-deep, so we could not get into it and walk erect without being noticed by the groom. The only recourse was to get down on our hands and knees and crawl inside the ditch all the way to the bus stop, some 100 metres away. Our elbows and forearms were scratched all over, while our trousers and shoes badly needed a laundry wash and a shoe-shine. But we managed to reach the bus stop and scramble in when a bus arrived.

But this was one occasion when a couple of hundred legs would have helped us a lot in the ditch!

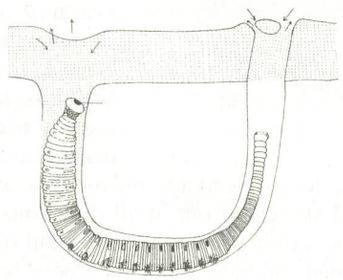


Fig.138 **Lugworm**

The lugworm (*Arenicola cristata*) elsewhere is found on clean sandy beaches, but at Mumbai it was discovered in the filthiest possible habitat—the sewage outfall at Haji Ali Bay. Rather stout and some 25 cm long, with a greenish brown body, it makes a U-shaped tunnel by eating sand and mud as it burrows. Organic matter in the sand is digested and the waste is dafecated as mounds of ropy sand and mud at the entrance to its burrow. About a dozen of its body segments bear bright red, branching, tree-like gills.

Fig.139
Chaetopterus

Of the various Sedentaria, the Bull's Head or Vari-footed worm (*Chaetopterus*) is most interesting. It too lives in a U-shaped burrow, but this is lined with a dark green, tough, parchment-like tube secreted by the worm and externally coated with sand, pebbles and shell fragments. The two ends of the tube project for about 2 cm above the sandy mud of estuaries (creeks), but are constricted, looking like the straws used for sipping cold drinks. (The buried portion of the tube is much broader.)

Its body is divided into three distinct regions. The front region has nine closely packed segments with large parapodia with prominent bristles. Of the five elongated segments in the middle region, the first has two tentacles looking like a bull's ears, and the last three segments have fan-like paddles. These beat to create a current flowing through the burrow, bringing oxygen and food. The rear portion looks more like that of a typical worm, but the parapodia are more developed.

The worm is bioluminescent. To what purpose the worm shines is not known, as it lives permanently inside its burrow and cannot be seen by other animals. If lightly touched, only the part of the worm which is touched emits a glow, but the whole worm shines if the stimulation is greater.

Fig.140 **Sand-mason**

The tubes of the Sand-mason (*Pectinaria*) are sometimes found lying empty on the sandy beaches of estuaries. Up to 7 cm long, conical with a slight curve like an elephant's tusk, they are open at both ends. The lower end is wider than the upper. The worm makes it by cementing sand grains of a uniform size, one layer thick, on slime. The worm carries its tube while burrowing in sand until it is almost or completely buried. The tube is almost vertical and its narrow upper end projects just above the sand of the beach. Strong muscles attached to two fan-like long golden setae, called paleae, on the head enable the worm to dig.

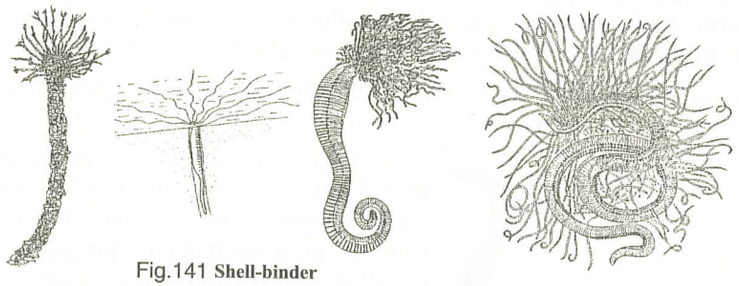


Fig.141 **Shell-binder**

The Shell-binder (*Terebella*) lives under stones on sandy shores with broken shell bits. It can be distinguish-ed by the numerous, long, slender, cream-coloured tentacles wriggling and stretching out in all directions. When a tentacle comes across a suitable sand grain or piece of shell, it is grasped and travels along a groove on the tentacle until it reaches the mouth, when it is seized by the lips and placed in position on the tube. But the tube is very fragile and breaks into pieces when lifted up. There are two or three pairs of short, red branched gills.

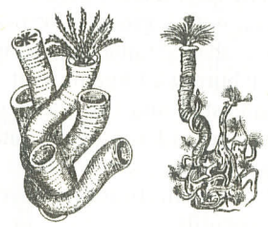


Fig.142 **Tube-dwelling worms**

Diopatra neapolitana makes a similar tube by cementing sand grains and bits of shells, but these are limited to the top 10 cm or so of the tube; its lower part is parchment-like. You can see a long but narrow patch a metre by 15 cm of tubes, separated by a gap from another patch, and so on. These discontinuous rows are parallel to similar continuous rows so as to cover a fairly wide area of sandy mud. In Mumbai mourners dump flowers and coconuts on the beach, so bits of coconut husk are invariably an ingredient of the tubes.

Although *Diopatra* lives in a tube, its body characters are typical of a wanderer (Errantia) rather than a typical tube-maker (Sedenteria), being closely related to *Eunice* or *Onuphis* (which look like giant nereids). Eyes are absent. There are five tentacles with ringed bases. Behind the head, the segments are similar. A few segments behind the head are bare, but behind these are about 36 segments bearing feathery gills in association with the parapodia; the gills in front are the longest. The worm is so thin and its tube so wide that the worm can turn around inside it.

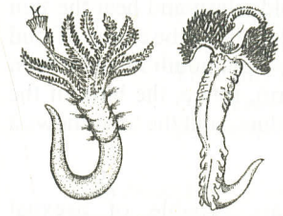


Fig.143 **Serpulid worms**

Next we come to the fan-worms. There are two main groups– those which make limy tubes by extracting calcium carbonate from sea water (serpulid worms) and those that make tubes from mud (sabellid worms). The former are popularly called Christmas tree worms, and the latter fan worms. Both together are called feather-duster worms.

The tubes of *Serpula* have irregular twists and turns, are white or light pink, and have ridges encircling the tube at intervals. They are found on stones and sea-shells.

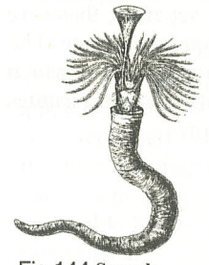


Fig.144 **Serpula**

Serpula has a tiny head region consisting of a prostomium hidden by two large palps (lappets). These are surrounded by 36 brightly coloured extensions of the lappets, which form a brilliant red tentacular crown. The tentacles are used as gills as well as for catching food and conveying it to the mouth by cilia (fine hairs). Each tentacular filament has a comb-like fringe on either side of a central stalk. One of the filaments is enlarged, being a blunt, club-like structure at the end of a long, narrow stalk. This is the operculum or lid and shuts the mouth of the tube when the worm withdraws into it. The sculpture of the lid is intricate, with ribbed sides and a vase-shaped extremity ending at the rim in a minute lobe. A subsidiary peduncle (stalk) next to the opercular stalk is sometimes enlarged, so that there are two opercula. The front portion of the worm is scarlet. There are five to seven segments in the thoracic (chest) region behind the head, followed by a long series of similar looking segments in the abdominal or tail region.

When the animal is undisturbed, the tentacles expand into bright red fans. But fan-worms are of a very nervous temperament. The slightest splash or even a shadow falling on them, makes them withdraw immediately into their tube. The fans come out of the tube after quite some time, and that too very slowly, as if they are unsure of their safety. The instantaneous withdrawal is possible because of the pressure of a row of tiny hooks on the upper part of each foot, extending halfway across the back, with the edges formed into long teeth. With seven teeth on a hook, and some 1,900 hooks, there is the combined pull of 13,000 to 14,000 teeth gripping the tube.

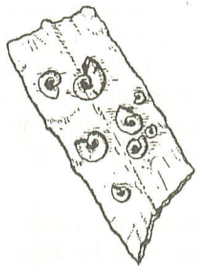


Fig.145 **Spirobis**

Spirorbis is another, very small, worm living in a limy tube built on the undersurface of rocks or the fronds of seaweeds. The tiny white shells are of the size of a pin-head and have a single, flat spiral. Its study would require the use of a microscope.

Sabella makes short (6 to 8 cm) straight tubes, about the thickness of a bicycle tyre valve-tube, from mud. Its "fan" is as pretty as in *Serpula*, being bright orange or sometimes banded with violet and white. It, too, is very nervous, and bolts rapidly into its tube at the slightest disturbance. It is fascinating to watch the worm building the tube. It rotates slowly inside the tube, and the thousands of cilia on the ribs of the gill-crown beat so as to form a loose clump of mud at the bottom of the funnel formed by the crown. The first segment of the body rises high above the mouth of the tube, and two parapodia, acting like trowels, fold, clasp and beat the thin edge of the tube, like our fingers kneading dough. As the clump of mud is sent down between the roots of the fans, the mouth mixes it with slime. As the plumes, along with the worm, rotate, the bulk of the muddy clump is seen to consolidate and reduce, and the tube shows a slight corresponding increase in its length.

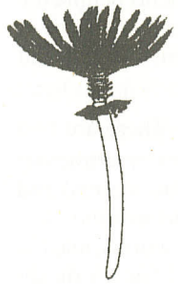
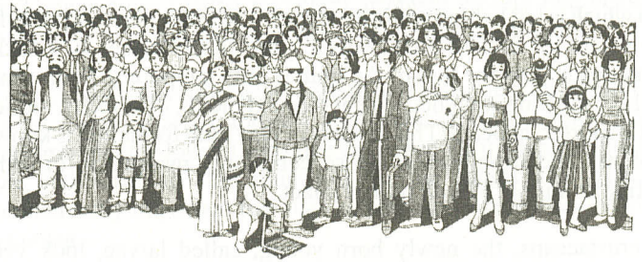


Fig.146 ***Potamilla***

Fig.147 ***Sabella***

Sabellid worms are capable of asexual reproduction by budding or by division of the body. Some sabellids are hermaphrodites, with the eggs and sperm developing in different segments of a worm. Generally, however, the sexes are separate; these are shed in the water where fertilisation takes place. The fertilised egg develops into a trochophore larva which swims among the plankton. Later it sinks and assumes the shape and habits of an adult worm.

18 The Motley Crowd



Fond man! yon glassy mirror eye
Go, pierce the flood, and there descry
The miracles that float between
The rainy leaves of watery green,
Old ocean's hoary treasures scan,
See nations swimming round a span.

Crustacea are a large heterogeneous group of various sizes and shapes, whose only common characteristic is that the body is covered by a hard crust on the exterior. They are the aquatic equivalent of the insects of land and air, and, with spiders and scorpions, centipedes and millipedes, belong to a vast assemblage called Arthropoda (meaning jointed legs).

The body is made up of jointed rings or segments but, unlike in the worms, the number of segments is much less, and each segment typically bears a pair of jointed appendages. In the larger and more well known crustaceans such as lobsters and crabs, the outer "shell" or "skeleton" is thickened with limy salts (calcium carbonate) which the animal extracts from the sea water. In the more primitive forms, the body wall is made, as in insects, of a substance called chitin. As a rigid outer shell would make it impossible for the animal to move, the outer skin at the joints is thinner and devoid of limy salts. .

Although the number of segments in different crustaceans varies, there is uniformity in the first six elements (i.e., the head). The first segment has no appendages, but the second and third segments carry a pair of antennules and antennae respectively. The fourth segment has a pair of jaws (or mandibles), the fifth the first maxillae, and the sixth the second maxillae.

As a result of the hard shell, continuous growth is not possible, as a bigger body (due to growth) would have no space to expand in. Growth, therefore, takes place intermittently. The body remains of the same size over a period of time, after which the outer shell splits open and the soft creature comes out of the old shell. The new shell takes some time to harden, and, during this interval, the soft animal grows a little bigger. The process of periodically casting off the outer skeleton is called moulting or ecdysis. After the new shell has hardened, the animal is unable to grow until the next moult. When a crustacean is young, moulting takes place every few days; the interval between moults then increases to weeks, and later to months, as the animal ages until,

finally, there may be just one moult in a year.

Crustaceans have the ability to voluntarily shed their limbs– a process called autotomy. This is a good defence when an appendage is held by an enemy. The victim just breaks off the limb which is left behind while it escapes. The break occurs at specific places along the limb where the broken blood vessel immediately closes so that the animal will not bleed to death. And the loss of the limb is only temporary. Soon a bud develops at the base where the limb was shed and, at the next moult, a perfectly formed new limb (though a little shorter) appears. This process of new limb formation is known as regeneration. Autotomy and regeneration are so commonly resorted to in some groups that it is rare to find an animal with all its legs intact.

In almost all crustaceans, the newly born young, called larvae, look very different from the adults. Most of the primitive forms, and some advanced ones like barnacles and prawns, start life as a nauplius larva. The larva swims among the plankton (drifting plants and animals), moults to become larger, gradually changes its body shape until it looks like a miniature adult. The name "nauplius" comes from that of a son of the Greek sea-god Poseidon who was a great navigator.

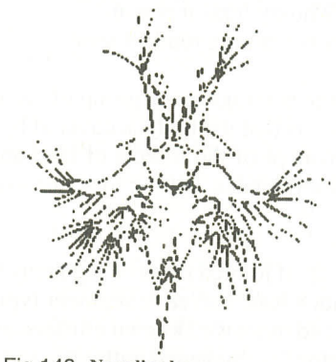


Fig.148 **Nauplius larva**

The naulplius's oval, pear-shaped body ends in two spines. The three pairs of flattened appendages fringed with long stiff hairs are used for swimming. Many crustaceans have eggs hatching into nauplii which drift in the plankton, but in some this stage is gone through in the mother's brood pouch or inside the egg, so that the form that comes out is an advanced larva.

The adult body shows two main regions. The front– a result of fusion of the head and chest (thorax) is called cephalothorax, and the rear part is the abdomen. The segments of the abdomen can be seen as (usually) seven jointed rings, but the cephalothorax is usually covered by a shield-like carapace. But as each segment typically bears a pair of appendages, it is possible, by counting these, to find out how many segments the cephalothorax is made of. The number of limbs may vary from three pairs to over twenty pairs.

The first two pairs of appendages on the head the antennules and antennae are swimming organs in the lower crustaceans like copepods and water-fleas, but they serve as sense organs for touch, smell, etc. in the higher forms. The antennules in prawns and

lobsters have an organ of balance, called statocyst, by which the animal can sense whether it is upright or upside down.

On either side of the mouth is a horizontally moving jaw. Behind these are a few head appendages (called maxillae) arranged closely one behind the other, used for holding the food and shoving it towards and into the mouth.

Crustaceans play an important part in the general economy of the sea. While the higher forms prawns, lobsters and crabs, constitute important fisheries for human consumption, the lower forms like the copepods make up in numbers what they lack in size and form an important link in the food-chain. The abundance of many commercially important fish such as herrings is dependent on the number of copepods in the sea.

The class Crustacea is subdivided into five subclasses: the Branchiopoda, Ostracoda, Copepoda, Cirripedia and Malacostraca.

Branchiopoda (= gill-footed) have a long body with many segments and leaf-like swimming legs. The brine shrimp (*Artemia salina*) are the best known marine forms, being found in salt pans; they are equivalent to the fresh water fairy shrimp. About 12 mm long with an orange-pink body, they are parthenogenetic, i.e., the eggs do not require to be fertilised by sperms. The result is that, most of the time, only females are seen, swimming on their backs with the help of 11 pairs of legs and carrying a ball-like mass of dark cysts (eggs). Only occasionally does one come across a male, with its huge spade-like antennae used for clasping the female. The cysts can remain dry for a long time without losing their viability, and will hatch into nauplius larvae within a day after being placed in sea water. Thus young nauplii can be obtained at will from the dry cysts. This is a boon to breeders of pet fish and in prawn culture, where the young are small in size and require still smaller food to grow. The cysts are therefore in great demand.

Fig.149 **Brine shrimp**

The cysts are available in salt pans all over India, but one should know at what stage of salt production they can best be collected. Salt production is not just a simple procedure of letting seawater into the salt pans and evaporating it to dryness. Sea-water is a mixture of many salts, some of which lend a bitter taste to it. Only sodium chloride has the typical saltish taste. As the sea-water evaporates, gypsum precipitates first, when the solution is concentrated to approximately three times. This takes place in the condensing ponds, where the water is usually green or brown.

Other salts still remain in solution, so the water is transferred to crystalising ponds. Here the water is concentrated ten times normal, when salt (sodium chloride) precipitates. The water here is red or pink, and contains the brine shrimp cysts. The remaining water, called bittern, contains dissolved magnesium and potassium salts; it is drawn off and discarded, leaving behind a bed of pure, white salt.

Various colouring agents, including green algae, red halophilic (salt loving) bacteria and beta carotene-producing substances are used in salt pans to raise the temperature of the water and increase evaporation. 2-naphthol green can increase salt production 5 percent over ponds using green microorganisms, and 40% over uncoloured brine ponds.

When collected, the cysts are mixed with empty cysts (egg shells). To separate the good cysts, advantage is taken of the difference in weight of the good and empty cysts; the former are slightly heavier. The mixed lot is fed into a hopper (a funnel-like device). Behind the hopper is a fan. As the cystsdrop down from the hopper, the lighter empty cysts get heaped at a greater distance than the good cysts, which can now be gathered and bottled, while the other heap (of empty cysts) is discarded.

It was a quest for *Artemia* cysts that led me to do some detective work. People believe that detective work is the prerogative of the police but even scientists with a curious and investigative mind can try their hand at it. This is what I did. Apart from salt pans along our coasts, there are three salt-lakes in Rajasthan. Sambhar Lake is the largest of the three the others being Deedwana and Pachbhadra. Sambhar Lake is also the largest single salt resource in India; about 27% of the total salt production in India comes from inland salterns, and of this 58% is contributed by Rajasthan. The lake is 35 km long and 9 km broad. Its area, when full, is 230 square kilometres, at which period its depth is 1¼ m. The quantity of salt in the lake is stupendous. Boring has shown that the salt layer is 21 m thick. (Just the uppermost 3½ m of this covers an area of 176 sq. km, which works out to 55 million tons of salt!)

There are various theories about the origin of all this salt. Sir Thomas Holland and Dr Christis believed that the salt-crust produced in the Rann of Cutch (a desert) from April to June is blown by monsoon winds, over distances of up to 515 km and at heights of up to 914 m, to be dropped into the salt lakes. Dr. Godbole believed that an arm of the ancient Tethys Sea which surrounded the Himalayas in the Eocene and Miocene epochs withdrew and left the salts behind. But the most entertaining explanation is a legendary story. Around 551 A.D., as the story goes, a tribe of Chowhan Rajputs of Sirthula village offered milk to a thirsty ascetic. The Godess Shakambari Devi was so pleased at this magnanimity that she converted a forest into a vast plain of precious metals. (Talk of the Midas touch!) The inhabitants, simple as they were, looked upon this gift as a curse instead of a blessing, as they felt it would lead to endless feuds. They requested the Godess to retract her favour, but the Godess being magnanimous, transformed the silver to salt.

Since my sojourn at Sambhar Lake was to be a brief one, I spent all my time there collecting cysts. This was easy, since the cysts accumulated in vast stretches of the water surface at the downside of the lake. After bringing them to Mumbai, we put the cysts to hatch in salt water, but they failed to hatch. This was strange, as the cysts appeared to be viable, and were properly collected and dried. On a hunch, I prepared several batches of salt water, varying from fresh water to that of sea water. Imagine my surprise when I found that the cysts hatched in freshwater, but failed to do so in sea water. When I grew the nauplii from these cysts (in fresh water), the adults did not have the size of brine shrimp, being much larger. Moreover, the pair of appendages on the head of the adult male, which are used for clasping the female while mating, did not have the spade-like appearance found in brine shrimp, but were branched. I found that it was not a brine shrimp, but was the fairy shrimp *Branchinella biswasi*.

On getting to know the salinity of the Sambhar Lake water in different months, the story was pieced together. Both the brine shrimp and the fairy shrimp live in this lake, but not at the same time. Immediately after the commencement of the rainy season the water in the lake is fresh, and it is now that the cysts of the previous year's fairy shrimp which have been lying on the dry lake bed, hatch. The animals soon attain maturity, but during this time the lake is gradually getting saltier due to the dissolving of the salt deposited in its bed. After a time the water becomes so salty that the fairy shrimp can no longer survive. It lays a batch of eggs and soon dies. By now the water has become salty enough for last year's brine shrimp cysts to hatch. Since, by this time, the fairy shrimp are all dead, the field is left open for the brine shrimp to grow and breed without any competition. Just prior to the lake's drying up, the brine shrimp too lay their eggs and die thereafter. The lake once again becomes a lifeless desert, with its dry bottom encrusted with a dazzling layer of salt looking like a vast sheet of snow.

Other branchiopods are *Evadne* and *Podone* with four to six limbs, small antennules, and large two-branched antennae used for swimming. These are placed in the Order Cladocera (= branched horn, referring to the antennae), to which also the well known fresh-water water-flea (*Daphnia*) belongs. Here, too, most of the animals are females, which carry their eggs in a pouch covered by the bivalve shell.

The Ostracoda (e.g. *Cypris*) do not show any segmentation of the body, which is enclosed in two valves hinged to form a shell similar to clams and oysters. There are eight pairs of appendages.

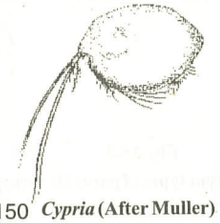


Fig.150 *Cypria* **(After Muller)**

The Copepoda (= oar-footed) are likened to sheep on land. Occurring in huge numbers, they "graze" on the abundant phytoplankton and, in turn, are a food for larger animals and fish. In their numbers they rival the insects on land. The elongated body, from 3 mm long to the size of a rice grain, has a cephalothorax of 3 to 5 free segments, bearing antennules, antennae, mandibles, first and second amaxillae, maxillipeds and five pairs of double-branched swimming feet. The cephalothorax is abruptly constricted to continue into a narrow abdomen lacking appendages.

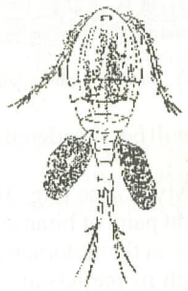


Fig.151 **Free- living Copepod**

The Cirripedia or barnacles will be considered in a separate chapter. The eggs hatch into a nauplius which then changes to a cypris stage.

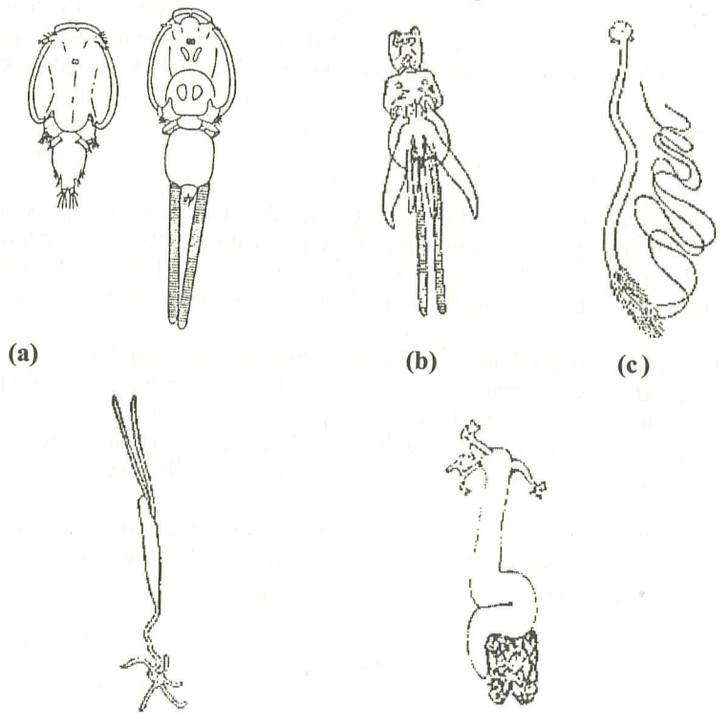


Fig.152
(a to e) Different types of parasitic Copepods

The subclass Malacostraca has eight orders.

The order Leptostraca is represented by *Nebalia* in which the carapace (head-fold) covers but does not fuse with the thoracic segments. There are seven abdominal segments more than the usual six of Malacostraca.

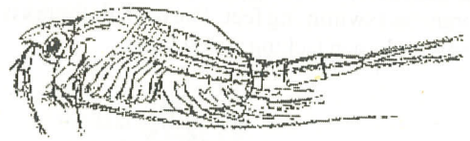


Fig.153 ***Nebalia*** **(After Claus)**

The order Stomatopodo will be considered separately.

In animals of the order Mysidacea (e.g. *Mysis*), the carapace overlaps the last thoracic segments. There are eight pairs of biramous (two-branched) thoracic legs, five pairs of biramous swimming legs on the abdomen and a sixth pair called uropods which form a tail-fan. The outer branch of the telson each carries a concretion of calcium carbonate (called statocyst) which is a balancing organ. The eggs are carried in a brood

pouch made by plates from the bases of some of the thoracic legs. Though the eggs hatch out as nauplii, they develop further within the brood pouch until they become miniature versions of the adult, when they emerge into the water.

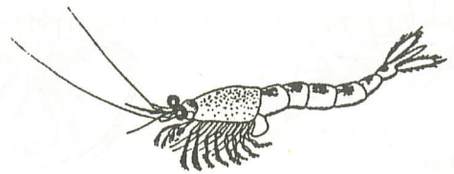


Fig.154 ***Mysis***

The Cumacea also have a carapace which does not cover the last four or five thoracic segments. The carapace is much broader than the long, narrow abdomen.

Fig.155 ***Diastylis*** **a Cumacean (After Sars)**

Fig.156 **A free-living Isopod**

Fig.157 **A parasitic Isopod (After Miner)**

The sand-fleas (order Isopoda) are dorso-ventrally flattened, (i.e. from above downwards). There is no carapace, but the first thoracic segment is fused with the head, leaving seven segments free, each with a pair of walking legs. The abdominal appendages are all similar and are modified as gills. The body is spindle-shaped or a long cylinder. Many of the isopods are free living, while many are parasitic on fishes and prawns and have a broad, ovoid body. The young, when hatched, are miniatures of the adult.

Some free living isopods, like the gribbles (*Limnoria*) burrow in wood and cause a lot of damage to wooden jetties. Pill-bug (*Sphaeroma*), so called from its habit of coiling its body like an armadillo, burrows in mud, soft rock and sandstone as well as in wood.

The sand-hoppers (order Amphipoda) are laterally flattened, so that they cannot "stand" but fall down on their sides. The gills are attached to the thoracic legs. The first

three pairs of abdominal appendages are used for swimming, and the three hind pairs for jumping. The young emerge from the brood pouch as miniature adults. A planktonic form, *Phronima*, makes its home in the barrel-shaped body of a tunicate.

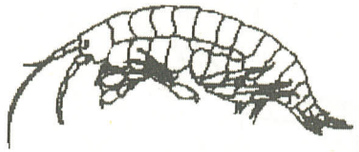


Fig.158
Gammarus, common sand- hopper(Amphipod)

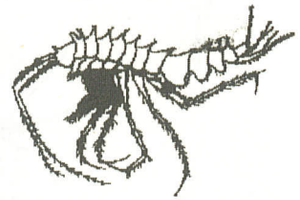


Fig.159 ***Lepichinella*, a deep- sea Amphipod**

The skeleton shrimp (*Caprella*) are grotesque, thin-bodied, with three pairs of clawed grasping legs on the thorax and three pairs of appendages on the tiny stump-like abdomen. They live among hydroid colonies, sea-mats (*Polyzoa*) and seaweeds.

Fig.160 **Skeleton shrimp (an Amphipod)**

The tiny (9 mm) *Chelura* bore into wood and damage jetty piles.

Whale lice (*Cyamus*) is a parasite on whales, turtles and some fishes.

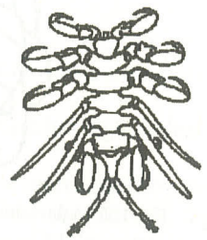


Fig.161 **Whale louse, *Cyamus* (an Amphipod)**

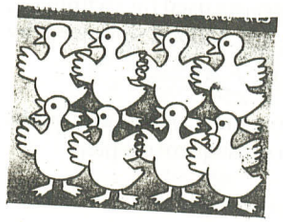
Although amphipods are not a usual item of human diet, they did save the lives of a number of men of Greely's ill-fated expedition to the Arctic (1883-84), who survived for weeks on nothing but amphipods. It is estimated that they must have consumed some 68 kg of these.

Fig.162 **Krill**

The krill (order Euphausiacea) are important shrimp-like creatures found in large numbers in cold seas as they form the main item of diet of baleen whales. The carapace is fused with all eight thoracic segments, each of which bears a pair of biramous legs and gills. The six pairs of abdominal appendages are used for swimming, and the last pair forms the uropods. The larval stages are nauplii, followed by calyptopia, furcilia, and finally cyrtopia.

The last order, Malacostraca, in which the first three pairs of thoracic limbs (called maxillipeds) are used for feeding, will be described in subsequent chapters.

19 The Birds and the B's



Thousands of barnacles, small and great
Stick to the jolly old ship of State
So we mustn't be cross if she seems to crawl
It's rather a marvel she goes at all.

A.P. Herbert

Barnacles—they are the *bete noire* of biologists, a nuisance to sailors, and a source of curse-words for any beachcomber unlucky enough to have slipped on a rocky shore and be cut by their knife-sharp 'shells'.

There are some 720 kinds of barnacles in the seas (but none in fresh water), and they come in two categories the rock or acorn barnacles and the stalked ship's or goose barnacles. Acorn barnacles (which are themselves different from rock barnacles) grow on rocks, and also on the skin of whales and the carapace of turtles. They look like miniature volcanoes, or a cone or pyramid with a hole at the top. The flat base is firmly cemented to a rock, and the sides of the cone are formed by six, or sometimes four, and very rarely eight, limy plates. The top is closed by two doors, each made up of two plates

Fig.163 **Acorn barnacles**

Rock barnacles are the most numerous and conspicuous animals to be seen at low tide. A kilometre long stretch of rocky shore may have a thousand million of them, varying in diameter from less than a centimetre to over 6 cm. Because of the limy 'shell', even two hundred years ago barnacles were thought to be molluscs. It was only in 1829 that a doctor, J. Vaughan Thompson, found that a barnacle's babies were similar to those of crabs, and deduced that they were related to lobsters, prawns and crabs.

Barnacles are found from the highest high-tide zone downwards to the surf zone, but do not thrive in calm waters. Depending on the species, they may live from one to seven years. But their life span and rate of growth depend on the height that they live on the shore. Thus, in the first year, barnacles that live lower down grow faster and spawn at one year, and die in the third year. Those higher on the shore spawn only in their second year but live for five years or more.

At ebb tide there is no movement, no sign or suggestion of life. But, when submerged, the top flaps open, and from the slit-like opening six pairs of branched, slender feathery appendages emerge. They come out and, like a hand with bent fingers, curl over with a grasping action, and then, like a clenched fist, close and withdraw into the shell These legs, beset with bristles, act like a sweep-net, collecting minute food particles. As the tide ebbs, the plates at the top shut tight, enclosing a little water which serves for the animal's breathing until the next high tide. It is this feeding action which led T.H. Huxley to remark that a barnacle is a "Crustacean fixed by its head and kicking its food into its mouth with its legs."

Charles Darwin also studied barnacles, and psychologists have been able to gauge his varying moods from his statements. In 1848 Darwin called them "my beloved barnacles". But in 1849 they had become "my confounded Cirripedia". His despondent mood continued in 1852 when he stated, "I hate a Barnacle as no man ever did before". But in 1853, he wished he could study them: "All nature is perverse and will not do as I wish; and just at present I wish I had my old barnacles to work at ..".

The reason why barnacles are so unpopular with sailors is because they settle and grow on ships' bottoms. A layer 50 to 75 mm thick on a ship's hull can weigh over 100 tons and slow down its speed by 10 per cent, while increasing fuel consumption by 40 per cent. Methods to discourage their settling on boats were known as far back as 412 B.C., when a mixture of arsenic and sulphur was used. Later wooden ships were protected by tallow and sulphur coatings or by thin sheets of lead or copper fixed below the water line. Nowadays, anti-fouling paints containing compounds of copper or tin are used.

Barnacles are considered to be an unmitigated nuisance, but on one occasion they were appreciated. When the whale ship 'Essex' was sunk by a sperm whale in 1820, after 25 days adrift, the survivors found barnacles on the bottom of their boat which were large enough to eat.

A classic example of transplantation of barnacles from one country to another is of *Elminius modestus*, a native of Australia and New Zealand. It was noticed near the Isle of Wight (in the English Channel) in 1943, brought there inadvertently by a warship. By 1950, it had colonised the whole of coastal England. In 1955 it reached Scotland and in 1957 it crossed over to Ireland.

Fig.164 **Barnacles mating**

The barnacles is a hermaphrodite, which means that an individual is both a male and a female. But an isolated barnacle cannot breed. This is where the profuse growth of barnacles in close proximity helps. The sperm from one animal is transferred to its

neighbour by a tubular mating organ. Unlike in Charles Dicken's novel "Little Dorrit", where the Barnacles are a human family of nine bungling incompetents, barnacles are very productive. On an average, a single barnacle will bring forth over 9,000 young every year. The fertilised eggs remain within the parent's shell for several weeks before being discharged into the sea.

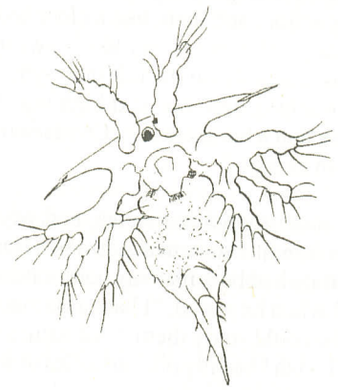


Fig.165 **Nauplius larva of barnacles**

Unlike human babies which resemble adults except in size, the newly hatched young, called nauplius larvae, look very dissimilar. The nauplii have a roughly triangular shape and are about 0.25 mm long, with three pairs of appendages and a single eye. They seek the light and drift about in the surface waters, feeding on algae. They moult (i.e. shed their skin) six times as they grow.

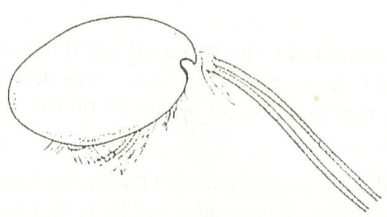


Fig.166 **Cypris larva of barnacle**

At the sixth moult, the animal changes shape and acquires an oval, hinged bivalve shell like a clam. There are now six pairs of appendages. Biologists call this stage a cypris larva. The cypris now seeks the sea bottom, walking about with its first pair of antennules. It is very choosy about where to settle, and may walk about for an hour before it finds a place to its liking–preferably a groove or a pit rather than a flat surface. It will align itself with the long axis of the groove. On a flat surface, it will align itself either along the direction of light or the direction of the water current, preferring the former if the two conflict.

Once it has decided its spot, the cypris larva sticks to it by means of a glue secreted by the antennules. The tissues reorganise, it moults, the shell of the adult develops in 12 hours, the appendages at the rear end elongate to form the feathery feeding cirri, and the body turns over. The result is an upside-down adult in its limestone house.

Some kinds of acorn barnacles live attached to the skin of whales, sometimes in great numbers. Though they are not parasites, they can be a source of irritation to the host.

Most species of whale barnacles are endemic, i.e., they attach to just one species of whale. And some are so selective that they are found only on one particular part of the whale's body. For example, the 'crown of glory' barnacle attaches to the lips and front edge of the flippers of humpback whales, while another species of barnacle resides in this whale's throat and ventral grooves. They often face into the current, taking advantage of the flow of water along the whale's body to obtain food.

Like all Crustaceans, barnacles also moult periodically. The outer skeleton covering its feathery appendages (called cirri) and the lining of the mantle cavity within which the animal lives, are shed. But the calcareous plates that surround and protect the animal are not shed. Instead, they expand, increasing in thickness, height and diameter by continual secretion of material by the mantle tissue. Thus the internal-cavity size increases at every moult, providing room to accomodate the larger animal after each moult.

Fig.167 **Goose or stalked barnacle**

Stalked barnacles settle only on floating pieces of wood or pumice. They are called ship's barnacles, but this is rather a misnomer today. In the days of wooden sailing ships on slow, long ocean voyages, they were able to stick onto the ship's hulls. Today, they have little chance of attaching themselves to fast steamers except in harbours; sessile acorn barnacles are the ones found nowadays on ships.

Fig.168 **A "barnacle tree" giving birth to geese**

People are often intrigued by its name, which goes back to the middle ages. Seeing stalked barnacles on drifting tree trunks, they mistook them for the fruits of the tree. To them, the feathery cirri seemed to be the tail feathers of a bird. A myth grew that barnacle geese originated in the fruit (so goose barnacles) of a tree that grew on certain shores. We may laugh at it today, but even in a scientific paper in 1677 in the

Philosophical Transactions of the Royal Society, Robert Moray wrote:

"I saw lying upon the shore a cut of a large *Firr*-tree... Only on the parts that lay next to the ground, there still hung multitudes of little Shells, having within them little Birds ... supposed to be *Barnacles*... This Bird in every Shell that I opened, as well the least as the biggest, I found so curiously and completely formed, that there appeared to be nothing wanting, as to the external parts, for making up a perfect Sea-Fowl: every part appearing so distinctly, that the whole looked like a large Bird seen through a concave or diminishing Glass."

So slow Bootes underneath him sees,
In the Icy Isles, those Goslins hatch'd of Trees;
Whose fruitful Leaves falling into the Water
Are turn'd, they say, to living Fowles soon after;
So rotten Sides of broken Ships do change
To Barnacles: O Transformation strange!
'Twas first a green Tree, then a gallant Hull,
Lately a mushrum, then a flying Gull

And from the most refined of Saints
As naturally grow miscreants,
As Barnacles turn Solend Geese,
In the Islands of the Orcades.

A soft and sappy gum, from which those tree geese grow,
Called barnacles by us, which like a jelly first
To be beholden seem, then by the fluxure nurs'd,
Still great and greater thrive, until you well may see
Them turn'd perfect fowls, when dropping from the tree
Into the mercy pond which under them doth lie
Wax ripe, and taking wing away in flocks do fly.

The barnacles with them, and which wheresoe'er they breed
On trees or rotten ships, yet to my fens for feed
Continually they come.

From Dreytons's *POLYOLBION*

A cousin of these barnacles, named *Saculina*, is a parasite on crabs. The adult looks like a fleshy bag on the lower surface of the crab's abdomen, but it has nauplius and cypris larvae similar to those of barnacles. A male crab affected by *Sacculina* apparently changes its sex; it looks like a female, but cannot function as one. The testes atrophy; the triangular abdomen takes the broad female shape, the mating organs become stunted, and four pairs of feathery, female-type abdominal appendages appear.

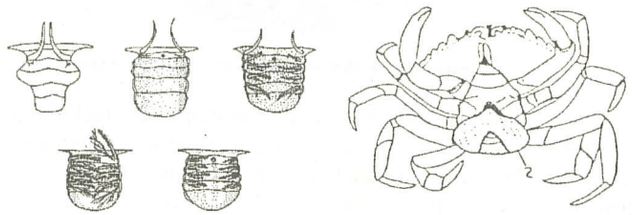


Fig.169 ***Sacculina* (s) parasite on crab**

I have had several 'encounters' with barnacles, but the one I shall never forget was a comedy of errors. Midway between Raj Bhavan and Prongs Lighthouse of Mumbai is an islet, which is submerged most of the time, except during spring tides on three or four days every fortnight. Since hardly anyone ventures there, it has a lush growth of seaweeds and sea-life. One summer, I had taken along a group of friends on our 15-m research boat, which anchored some 50 m off the islet. We got off by batches in a small dugout canoe.

While returning, the dugout continually got swamped and filled with water as people tried to sit in it. While manoeuvring the canoe, the swell knocked off my friend, who slipped and got his whole back cut by hundreds of barnacles. I was trying to steady the canoe by levering myself on my extended leg, when a wave pushed the canoe onto me. Had I not withdrawn my leg, it would have come under the canoe and got broken. As I slipped, the inside of my right thigh was completely lacerated by barnacles. When I reached home, to avoid worrying my mother, I quietly applied mercurochrome on the myriad cuts and went to bed.

The next morning I was to accompany a batch of oceanographers on our research boat to test some equipment. This involved an eight-hour stint. I had forgotten to apprise my office people about this programme. Next morning, one of the picnickers of the earlier day telephoned my office to enquire about my leg. Finding that I was not in, he told the Curator that he had seen the dugout canoe capsizing over me and was sure (!) that I had fractured my leg.

Meanwhile, after a tiring voyage on the boat, I arrived home in the afternoon and decided to take a short nap before attending office. Alas! This was not to be. The Curator, in his anxiety, came to my house, rang the doorbell, and as soon as my mother opened it, rushed into the bedroom and pulled up my pyjamas to ascertain the extent of my injury. The red mercurochrome all over my thigh heightened the gory effect of my wounds. My mother refused to believe that my leg was not broken, and to convince her, I had to get up, get dressed and leave the house to attend office!

Superglue from Barnacles

Since barnacles have to withstand the violence of pounding surf, the cement that they produce to stick to rocks has to be really tough. If a barnacle is removed from its shell, a yellow, jelly-like mass is left behind, containing a series of paired glands. It contains a thick pale brown fluid of the consistency of motor oil. This is the barnacle glue or cement.

A layer of this glue just 0.0025 mm thick has a shear strength of 495 kg per square centimetre. Barnacle glue heated to 350° C softens slightly, but does not melt. (Lead melts at 325° C.) Even when dipped in liquid nitrogen (230° C below zero), it does not crack or peel. Moreover, it does not dissolve in strong acids, alkalis, organic solvents or, of course, water. And it is long lasting. Fossil barnacles stuck 15 to 20 million years ago have not come loose even today.

Once the glue is chemically analysed and synthetically produced in the laboratory, scientists envisage that it will have a wide variety of uses in bonding anything to anything metals, plastic, glass, in construction industry, and even to stick broken bones.

20 Salty Knight in Armour

Of metal was her armour bright,
With gems of many colours overspread;
The tawny jacinth, yellow chrysolite,
The emerald green of hue and ruby red.

Lumped together as "shellfish" are two diverse groups of animals one comprising oysters, clams and snails, and the other of lobsters, prawns and crabs. The latter comprise the Decapoda or ten-footed animals a sub-group within the Crustacea. They are all well known, being a gourmet's delight.

While the outer "shell" is thin in prawns, it is thicker and harder in lobsters and crabs because of deposition of lime. This hard shell or outer "skeleton" is wonderful as protective armour against enemies, but it constitutes a serious obstacle to continuous growth. While we, with our skeleton inside our body, can grow steadily from a boy to a youth, the "shell" prevents this in Crustacea. This handicap is overcome in a unique way. From time to time, lobsters (and all other Crustacea) cast off their outer skeleton. The shell splits, and the soft animal creeps out of it, as if discarding an old shirt or coat.

It's like as one layeth
One's worn-out garb away,
And taking a new one sayeth,
"This will I wear today."

While still soft, the lobster increases a little in size. At this time, the soft creature is vulnerable to its enemies and therefore hides in a crevice or cranny among rocks. The new "shell" now hardens, and further growth stops until the next time the shell is again cast off. This process of removing the shell is called moulting or ecdysis, and occurs frequently while the animal is young, but at longer intervals as it grows older.

Another unique feature is the ability of an animal to automatically throw off a limb. If you hold a lobster (or crab) by its leg (or claw), you will be left holding the limb while the animal drops to the sea bottom and scuttles away. The limb breaks off at a particular place, where a flap closes to prevent loss of blood. And this autotomy or self-amputation is not a permanent handicap. A small bud soon appears where the limb was cast off and, at the next moult, a fully formed (though somewhat shorter) limb appears. The regeneration of a lost limb is somewhat akin to a lizard shedding its tail and growing a new, shorter one.

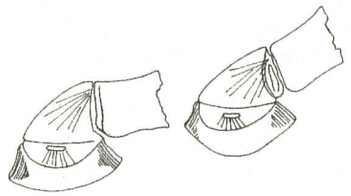


Fig.170 **The "breaking plane" on a leg where it can be voluntarily shed**

As the poet said:

Him they dismember'd often, and not slew;
Nor he, because dismember'd, ever dies,
For he remodels leg or hand like wax.

The hard skeleton is divided into rings or segments jointed on each other. While the outer shell is continuous, it is thinner at the joints, so that movement can be achieved. Each leg, or limb, is made up of hollow cylindrical segments, each joined to the next, but moving only in one plane. But as each successive joint is hinged in a different plane, the tip of the limb can be moved in almost any direction.

Our lobsters are different from the American and European lobsters (*Homarus*). These latter have two kinds of claws. A stout claw, armed with teeth similar to our molar teeth, is a crusher. The lobster uses this claw, which has powerful but slow-acting muscles, to smash open mollusc shells and for defence. The slender claw, which has numerous teeth like our incisors, is a cutter. Equipped with fast-acting muscles, it is used by the lobster to remove the meat from crushed shells, as well as in grooming.

There is an equal probability of either claw developing on the right or left side. The claw of the baby lobster are undifferentiated. External stimuli and behaviour patterns determine which claw will be bigger. Lobsters in their fourth and fifth juvenile stages, kept in tanks without sand or gravel on the bottom, i.e., without any material for the claws to grip on, developed similarly sized cutting claws. But when one claw was stroked three times a day with a brush, the lobster gripped the brush bristles about eight times in a minute. The stimulated claw then developed into a larger crushing claw.

Unlike the European or American lobsters (*Homarus* spp.), which have huge claws or pincers which serve to defend them against enemies, our lobsters do not have these. Instead, their body is armoured with many spines scattered all over the body, with two much longer ones over the eyes. To distinguish them, they are called spiny or rock lobsters (*Panulirus* spp.), or sometimes sea-crayfish or sea-crawfish. (Crayfish are fresh water relatives.)

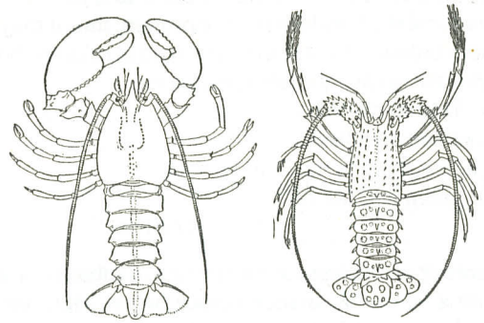


Fig.171
A true lobster (left), and a spiny lobster (right)

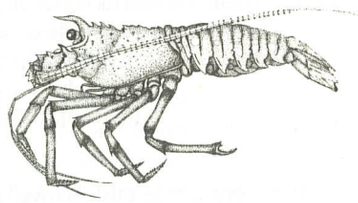


Fig.172
Side view of spiny lobster showing its armour of wicked spines

The origin of the scientific names for spiny lobsters is interesting. The ones in Europe are called *Palinurus*, after the pilot of Aeneas's ship who fell overboard, drowned and was immortalised by a cape (and the lobsters) named after him.

Unfortunately for our Indian spiny lobsters, their scientific name, *Panulirus*, in

Greek means "wholly lewd" or "without a trace of shame".

Scientists create different words by playing about with different arrangements of the same letters. Thus there are three isopod genera named *Cirolana*, *Lanocira* and *Anilocra*. All these are formed from the same eight letters of the alphabet. It is likely that the proposer of the name *Panulirus* tried the same strategy and inadvertently named *Panulius*, being ignorant of Greek and hence not realising the harm he had created.

The lobster's body has two main parts; the front half called cephalothorax, roughly equivalent to the head (cephalus) and chest (thorax) being fused together, and bearing five pairs of legs with which the lobster walks on the sea bottom. The rear half called lobster tail by the gourmet is actually its abdomen. On its lower side are delicate flaps called pleopods or abdominal swimmerets. While prawns swim with their help, in lobsters they serve as attachment for the thousands of eggs in the female. But lobsters can swim backwards for short distances by flapping their abdomen under the body repeatedly.

Fig.173 **Resting posture of a rock lobster, with abdomen tucked under the body**

Those who have seen cooked lobsters in restaurants imagine that lobsters are red (as they appear on the dining table). However, our spiny lobsters have colours varying from bluish grey to emerald green, depending on the species. The living lobster's colour is due to a complex made of a carotenoid, called astaxanthin, bound to a protein. By itself, astaxanthin is red, but this colour is masked (hidden) by the protein; thus it may be blue, yellow or red, or mixtures of these colours. Heat during cooking breaks the bond between astaxanthin and its attached protein, so that the lobster turns red.

Any colour, so long as it's red
Is the colour that suits me best,
Though I will allow there is much to be said
For yellow and green and the rest.

Eugene Field

But there can be quite a lot of colour variation in some species of lobsters. Thus, in some it is a dark green above, with a yellow to orange colour below. But, one in several million may be only blue or red. Albino lobsters, without any colouration also exist, but are even rarer than blue or red ones. Golden lobsters are rarer still. There are even lobsters with differently coloured, sharp demarcations. But, basically, all the colours of a lobster are a result of red, blue and yellow pigments, which may combine in many different ways to produce the overall colour pattern.

Scuba divers know that the sea is not silent. Contributing to the cacophony of sounds and noise under water are spiny lobsters. They make squeaky, scratchy sounds

by rubbing the joints of the long antenna (feelers) across the front part of their body.

Like their cousins the crabs, spiny lobsters hold their eggs under the abdomen. The female mates shortly after moulting, when the male turns her over and sticks two patches containing sperms on her underside Many days later, when the eggs are extruded, she scratches these patches with the tips of her legs to release the sperms which fertilise her eggs as they come out. Each egg has a little stalk, and the eggs are stuck to the swimmerets by a kind of glue secreted by the swimmerets. When freshly extruded, the eggs are orange-yellow, and the lobster is said to be berried or in berry. As the young grow inside, the yolk is used up, and they turn black. In due course, they burst and the larvae (babies) come out and drift in the sea over long distances, growing larger and moulting from time to time. These larvae are flat, glassy transparent, have long spidery legs and are called phyllosoma. They lead a planktonic life for 6 to 12 months, passing through at least 11 larval stages and increase dramatically in size. The body now changes into a glassy miniature of a lobster; this sinks to the sea bottom and soon moults into a baby lobster. In two years, it will grow to an average size of 5 cm in carapace length, and in three to four years this length will increase to 7.5 cm, weighing 0.7 to 1.4 kg.

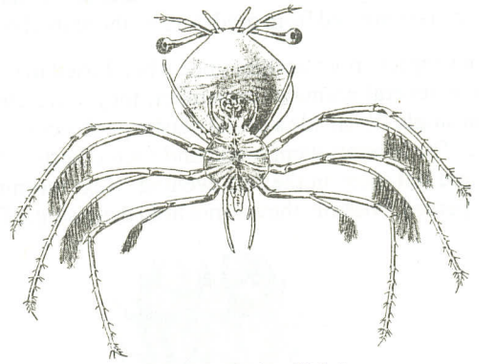


Fig.174 **Phyllosoma larva of lobster**

Because stale fish are used as bait for catching lobsters, they are mistakenly regarded as scavengers. Actually, they prefer live clams, mussels, sea urchins (and even a fish if they can manage to catch one). Despite their hard shells, spiny lobsters fall prey to groupers, skates and dogfish. It's easy to find out whether a lobster (or crab) is alive or dead. Squeeze its eyeball situated at the tip of the eyestalk between finger and thumb. If the animal is alive, it will flap its abdomen and wriggle its legs.

Lobsters should be handled carefully. You can hold them by the long antennae (feelers). When holding them by their cephalothorax, be careful not to have your hand around it, as the lobster will flap is abdomen and badly gash your hand. Sometimes I have wished that spiny lobsters could be hypnotised as the true (clawed) lobsters can, so as to hold them without being hurt. It's somewhat like hypnotising a hen. Place the hen's beak against the floor and draw a chalk line straight away from the tip of its beak. This trick seems to be an old one. For example, Rudyard Kipling, in his 1893 story "My lord the elephant" (one of the "Soldiers Three" series) has Ortheris saying, "Same as canaries. Draw a line on a board, put their beaks there; stay so for ever and ever they will." Or a hen can also be hypnotised by tucking her head under her wing and whirling it about. (But don't let the S.P.C.A. catch you!) For a lobster, stand him on his head, with the claws resting flat. Bend its tail slightly inward, stroke its back a few times and

remove your hands. The lobster will remain motionless, balanced on its rostrum (nose) and claws.

At the Taraporevala Aquarium, we have studied spiny lobsters in great detail, and have also raised some controversies. In the good old days (before the export of lobster tails began), 25 cm long lobsters could be had for 75 paise; now a 15 cm one fetches Rs. 25. As there was no detailed study on their fishing since 1933, I undertook a survey and was fortunate to record a fourth species*Panulirus dasypus*, at Mumbai. (The other three are *Panulirus polyphagus, P. homarus* and *P. versicolor.*)

Spiny lobsters are caught along rocky coasts (because they can hide in crevices after moulting, while the new shell is hardening), so my colleague raised a hornet's nest when he observed them in trawl catches. (Trawl nets are operated over muddy or sandy sea bottom.) His surmise that they also live on soft bottoms was pooh-poohed by "experts". But he was vindicated when it became known that spiny lobsters migrate in an offshore-onshore pattern. Off Bimini in the Bahamas, thousand of spiny lobsters march in single file over open areas. Each individual holds the tail of the one ahead of it by hooking with its front legs, or flicks it with its antenna to maintain contact. Thus the vulnerable abdomen is protected from predators by the animal behind.

I could not suppress my mischief once when I tried to see if this trait is found in our lobsters. I took several animals (remember, they were cheap in those days) and positioned them in single file inside a round plastic pool. I closed the ring by placing the animals in a circle. The lobsters went round and round for the better part of a day until I was finally tired and left them in the late evening. Next morning, when I came to see them, they had dispersed. Possibly they do not hold their 'single file' formation at night.

Fig.175 **Slipper lobster (*Thenus orientalis*)**

Close cousins to spiny lobsters are the squat lobsters, also called by various other names like flat lobster, slipper lobster, flapjack and, rather unflatteringly, sea-cockroaches. While most (such as *Scyllarus*) are quite small, one (*Thenus orientalis*) grows sufficiently large to be of commercial value. The front of the body is flat like a spade, but the abdomen is quite rounded. The front border of the body forms a straight edge, with the eyes right at the tips. The antennae are broad, flat, rounded plates with irregular serrated edges. When disturbed, it rolls up like a pangolin and tucks its legs under the flat body. This action, together with its orange-brown colour help it to survive despite the absence of any special defence organs. It is widely distributed from the Red Sea through India and Indonesia to northwestern Australia, down to 300 metres. It is also called bat lobster.

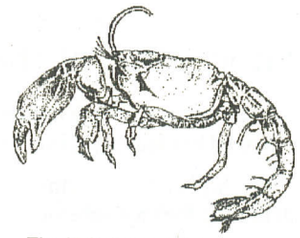


Fig.176 **Mud lobster**

The mud lobster *(Thalassina anomala)* is a nuisance to rice farmers who grow paddy in land adjoining creeks which is subject to occasional spring tide influence. Their bunds are weakened by the numerous burrows made by these secretive animals and may collapse occasionally.

21 Pinocchios* of the Sea

O! mourn not, that in nature, transitory
Are all her fairest and her loveliest things.

The higher crustaceans are also the larger and more familiar among the vast heterogeneous assemblage called the Malacostraca; the front part of the body comprising the head has six segments, followed by the thorax (chest) of eight segments, behind which is an abdomen of six segments followed by a telson. The most advanced Malacostraca are the Decapoda (meaning ten legs), comprising the prawn, lobsters and crabs (including hermit crabs). All these have ten walking limbs and are hence called Decapoda (meaning ten legs). Actually they are the last five pairs of appendages of the thorax, the three previous pairs having shifted forward to serve as accessory feeding appendages. The appendages on the abdomen are never more than six pairs, and are never used for walking. The Decapoda are split into the swimmers (Natantia), which swim using their abdominal appendages (called swimmerets), and the walkers (Reptantia) where swimming, if at all done, is by flapping the abdomen or with the help of flattened walking legs.

The Natantia are well known as they comprise the prawns and shrimps. The prawns again are divided into two main sectionsthe Penaeidea and the Caridea. There is some confusion about distinguishing the two sections. Our commercially important, large, edible marine prawns, such as *Penaeus, Metapenaeus* and *Parapenaeopsis* are all penaeids.

Americans use only the word shrimp for prawns also. The word "shrimp" is derived from *schrimpfen*, meaning shrunk or shrivelled. From Shakespeare downwards it has been used derisively for a runt. Most but not all Caridea are of a smaller size than the large edible prawns.

The major differences between the two are that the penaeid prawns release their eggs, after fertilisation, into the water, and that the third pair of walking legs have claws. Caridean prawns and shrimps carry their eggs under the abdomen until they hatch, and the third pair of walking legs never have claws.

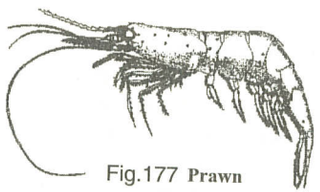


Fig.177 **Prawn**

Fig.178 *Acetes*

There are other differences also. Penaeid prawns have a long, saw-toothed horn or rostrum in front of the head. Some caridean prawns, such as *Palaemon* and *Macrobrachium* also have a rostrum, but most caridean shrimps have, instead, two forward directions, like a rabbit's ears, on each side of the head. Both the pairs of antennae in penaeid prawns are long and whip-like. In carideans, there are a pair of short branched antennae in front of the eyes and a pair of long slender antennae near the "rabbit's ears". Many carideans have a hump back. And while the eggs of penaeid prawns hatch into a primitive larva called nauplius, those of carideans hatch into a more advanced mysid stage, resembling *Mysis*.

Pinocchio was a wooden puppet whose nose grew longer every time he told a lie.

God hath given you one face
And you make yourselves another

Shakespeare *HAMLET*

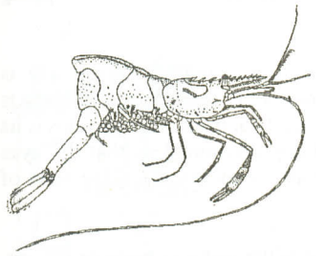


Fig.179 **Periclimenes**

A small (4 cm) but interesting prawn is the Aesop prawn (*Periclimenes*), so called because of the prominent hump on its back. (Aesop, famous for his Fables, was a hunchback.) It is extremely transparent, except for a few coloured spots on the body. The feelers on its head are held in a characteristic position. Of the first pair (antennules), the outer lash is held vertically, and the inner one horizontally forward. The long feelers of the second pair (antennae) are directed backwards most of the time.

Fig.180 **Macrobrachium rosenbergii**

Compared to most caridean shrimps which are small, the fresh water prawns (*Macrobrachium rosenbergii* = *Palaemon carcinus*, and *M. malcolmsonii*, grow to a very large size rivalling the biggest penaeid prawns. The adults are found in fresh water, but the young must have access to brackish water, otherwise they would die. This poses no problem to the former, which live near the coast, but the latter posed a hurdle, as in Maharashtra it is found at Nanded, which is situated on the river Godavari and is 800 km away from the sea. First I tried to rear the young in fresh water to find out if they really needed salt water. They did, so where could they find salt water? Obviously at the river mouth, but that was 800 km away!

Fig.181

As a young lad, I was fond of reading novels about the famous detective Sherlock Holmes, but I would never have believed in my wildest dreams in my youth that my turn would also come to do some detective work on my own. The mystery was solved when I studied the fishery along the river Godavari, which flows for some 1,400 km before it enters the Bay of Bengal. I found that at three places along the course of the river, as many as 14 to 19 tons of prawns were caught every year. The place nearest to the river mouth was Rajamundry only 80 km upstream, and the prawns caught here were either berried adult females (i.e., carrying eggs) or fairly small young (about 3 cm). The next place where a substantial fishery for these prawns existed is Sironcha, 450 km above the river mouth; here the prawns were slightly bigger and were caught several weeks later than at Rajamundry. Farthest from the river mouth where yet another fishery for the prawns flourished is Nanded; the prawns here were larger than those at Sironcha and were caught many weeks after their first appearance at Rajamundry.

Gradually the jigsaw puzzle was pieced together. The adult females did not have to migrate right up to the river mouth. They carry their eggs attached to the swimmerets on the belly, and when these hatched, the tiny young were swept downstream by the river flow. They reached the river mouth just at the time when they needed salty water for their further growth, and grew in the brackish water. Their need for salt water over, the young dropped to the river bottom where they crawled laboriously upstream.

The gradually increasing size at the three fishing centres, and the fact that they were caught earliest when near the river mouth, and at a later date farther up, corroborates the surmise that the young walk back all the way upstream until they reach the place where their parents lived. The young reached a length of 20 to 30 mm in a month. Ultimately, males grow to a whopping 187 mm, while the females are smaller, upto 158 mm.

Fig.182 *Lucifer*

At the other end of the spectrum (as far as size is concerned) is *Lucifer*, found commonly in plankton. Its body is transparent, but what makes it stand out from other shrimps is its greatly lengthened cylindrical cephalothorax, so that the eyes and feelers are far removed from the mouth and three pairs of legs.

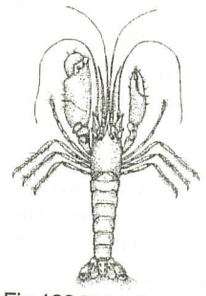


Fig.183 **Pistol shrimp (top view)**

Pistol shrimp (side view)

Another small caridean is the pistol or snapper shrimp. The name comes from the loud popping noise which it makes. Visitors to the seashore are often puzzled to hear this pop, accompanied by a stream of water. It is made by a small (3 cm) bottle-green shrimp, *Alpheus crassimanus*. Even a cursory glance shows that the two claws are vastly unequal; in fact, the larger clawed limb is almost as long as the shrimp. A more careful examination shows a knob on the finger and a corresponding socket in the thumb. There are also two tiny smooth patches one near the base of the finger, and the other at its joint with the palm of the claw. When the finger is opened wide, these two smooth patches act like suckers and stick to each other. The animal has to exert great force to overcome this suction; when the force is sufficient the finger snaps shut against the thumb, causing the popping noise and the stream of water. I have had many a glass beaker or jar cracked on keeping this shrimp in them. When the knob on the finger of the claw is thrust into the socket on the thumb, water from the socket is squeezed out at a velocity of 30 metres per second. Because the pressure becomes lower, the water vaporises. The vapour bubble grows in size but slows down in speed, so that the bubble collapses with the decreasing pressurea process called cavitation. Piston shrimps communicate in this manner; there may be as many as 10,000 of them on a mud flat.

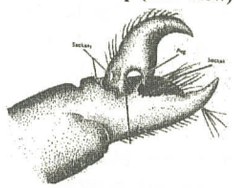


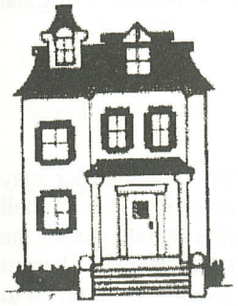
Fig.184 **Claw of pistol shrimp, showing knob & socket**

Fig.185 **Pistol shrimp from front**

The weed-prawn (*Hippolyte*) is another small (3 cm) shrimp. Its characteristic identity is that the segment of the second walking leg which is next to the claw is divided into numerous joints. The upper side of the rostrum is smooth, being devoid of saw-like teeth. Like a chameleon, it can change its colours. As Dryden wrote:

But yours is much of the chameleon hue,
To change the dye with every different view.

22 Home is where the Heart is



Mid pleasures and palaces
Though we may roam,
Be it ever so humble,
There's no place like home.

John Howard Payne

Millions of years ago, Nature played a cruel trick on one group of crustaceans. While all the others were provided with a hard outer covering, the hermit crabs were partially deprived of this. If you look at a hermit crab, you will see that the front half of its body and its legs are hard and well protected, but it has a soft abdomen. But the hermit crab did not accept defeat; it evolved a strategy to shield its vulnerable abdomen by tucking it inside an empty snail shell. And as gastropod shells have a spiral twist, the hermit crab's abdomen has also acquired a twist. In fact, most snail shells are right handed, i.e., if you hold the shell with its apex towards you, you will see that the twists are clockwise. Because of this, a majority of hermit crabs also have their abdomen bent to the right so as to fit snugly. Offer such a hermit crab a left-handed shell, and see how it tries in vain to fit its abdomen in it. It's like putting on a left shoe on our right foot.

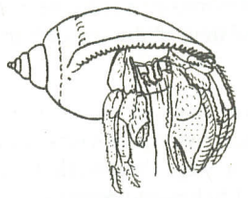


Fig.186
A hermit crab occupying a snail shell

The hermit crab is very choosy about its shell-house. As it grows, it finds that the shell is a tight fit, like a shrunken shirt. It then goes in search of a bigger shell. On coming across one, it will roll the shell around, poke its head and claws in to see if it is suitable. If satisfied, it will hold the shell so that its lip is close to the lip of the shell it is occupying, and in a quick move withdraw its abdomen from its house and thrust it into the new one. But it often maintains its hold on the old shell, dragging it as it walks on the sea bottom. This is just to ensure that the old shell is available to it if it finds the new one unsuitable. If so, it will abandon the new house and go back into the old one.

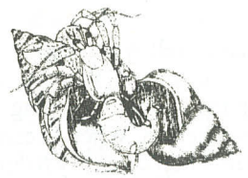


Fig.187
A hemit crab changing its "home"

I can understand why hermit crabs feel embarrassed when their naked abdomen is exposed to viewers. Until the late 1940s, people used to travel to Europe or U.S.A. by ship, there being no airlines. At that time, Aden was a bustling duty-free port where ships plying to and from Bombay docked for a few hours. In the little time at their disposal, ship's passengers disembarked to purchase cheap consumer articles. Nylon and terylene clothes had just come in fashion, so many of the passengers made a beeline to the ready-made clothes hawkers, especially those selling shirts, attractively folded in flat cardboard boxes with transparent cellophane front to show the collar and shirt front with buttons. Only when the hapless passenger opened it in the ship did he realise that he had been duped. The showily folded "shirt" was only a facade; it had only a front and no back or sleeves!

If the hermit crab does not find a suitable empty shell, it tries to usurp one already occupied by another hermit crab. The latter may withdraw further into its house or push the intruder away. The intruder will, in turn, try to pull out its legal occupant, rocking the shell back and forth to induce its tenant to move out. If it succeeds in this, the dishoused tenant will go house-hunting, or sometimes occupy the intruder's original house while the intruder goes into its new dwelling.

The short, the simple plan,
That they shall take who have the power
And they shall keep who can.

If the original tenant has retreated farther into its shell, the intruder may sometimes push its abdomen into the (occupied) shell. It will carry the occupied shell about until it comes across a suitable empty shell; often its original tenant pushes the intruder out by force. Because of the twist of the abdomen, different species of hermit crabs prefer to live in a particular species of snail shell. The larger claw is modified to close the mouth of the shell like a stopper, after the hermit crab has withdrawn into it. Hermit crabs of the family Paguridae have their right claw almost always larger than the left; the reverse is the case in the family Diogenidae. (The latter family is named after the Greek philosopher Diogenes, who is believed to have lived in a tub!)

Hermit crabs without shells are desperate to hide their exposure. They will try to make use of unusual objects like sea urchin tests (skeletons) or medicine vials. If nothing is available, they will sit disconsolately on top of their abdomen or bury it in sand.

The importance of having a proper residence was realised by me one early morning. I was then an assistant director in charge of many fishing trawlers. To avoid boredom, I welcomed scientists on board who wished to carry out their work. One such person used to snip off different tissues from freshly dead fishes and preserve them in alcohol. He could not come on one such trip and requested me to collect tissues for him. I had taken home a bottle of alcohol for this purpose.

My boats used to leave early in the morning, and as the distance from my residence to the fishing docks was short, taximen were reluctant for a fare, so I used to walk to the docks. Conditions on fishing boats are none too clean, what with the heavily greased winch cables which would soil your trouser legs if you were not careful to stay away. The slime from the fish was an added spoiler of clothes, so I used to wear a pair of old trousers and jersey, and monsoon slippers for wear on the slippery decks of the boats.

Around 3 a.m. I started from home, dressed in these well-worn togs, and carrying a sling bag with a towel, soap, tea and milk powder, sugar, and, this time an alcohol bottle. In the distance, I saw a policeman standing on the footpath, keeping an eye on any suspicious happenings. I had nothing to fear, so I walked on. When I neared him, he asked me to stop and tell him why I was out so early. I told him about my fishing boats, and who I was. Probably, keepers of the law think that assistant directors in government departments move about nattily dressed, in posh cars and generally throwing their weight around. And here I was, looking so unlike his concept of an assistant director, dressed in unkempt, bedraggled clothes and, of all things, walking! His suspicions fully aroused, he asked me what I was carrying in my shoulder bag.

It suddenly struck me that I was not carrying my permit for transport of alcohol. (Prohibition was strict then.) Slowly I took out, one after the other, the towel, the tea powder, all the while thinking of a strategy of what to explain at the police station where, I was sure, I would be marched off.

Suddenly the policeman asked me where I stayed. Apparently, the colony where I stay has a good reputation, so, the moment I gave him my address, he asked me to walk on. I was relieved, of course, but my thoughts at that time were not of my dilemma, nor the police, or even my fishing boats, but somehow strayed to the abode of hermit crabs.

The hermit crab is basically a loner, though we do find several of them feeding together on some delicious (to them) morsel like a dead fish. As Cowper puts it:

Wherein he dwells, he dwells alone,
Except himself has chattels none,
Well satisfied to be his own
Whole treasure.

Thus hermit-like, his life he leads,
Nor partner of his banquet needs,
And if he meets one only feeds
The faster.

Who seeks him must be worse than blind
(He and his home are so combined),
If, finding it, he fails to find
Its master.

Fig.188 **Hermit crab taken out of its "house**

To help them stay put and avoid being pulled out of their shell, hermit crabs have little claspers at the tip of their abdomen. These anchor the hermit crab so securely to its shell that the abdomen may be torn off but the whole animal cannot be pulled out. The trick is to hold a lighted match near the shell so as to heat it gently, when the hermit crab will leave it. Hermit crabs also abandon their shells if conditions are unfavourable. An easy way is to reduce the dissolved oxygen of the water in which they are kept, or change the salinity. I have often added fresh water or passed carbon dioxide through the sea water to induce a hermit crab to come out of its shell. Adding soda water is equally efficacious.

Like most animals, hermit crabs, too, have enemies. Box crabs (*Calappa*), stone crabs (*Myomenippe*) and spiny lobsters (*Panulirus*) feed on hermit crabs, either crushing their snail shell completely or, more often, chipping away the outer lip of the shell until the hermit crab is exposed. Octopuses are the greatest scourge of hermit crabs. The hermit crab's mobile home offers good protection, but many hermit crabs have an additional line of defence. They have sea anemones living on their snail shell. The subterfuge is advantageous to both the hermit crab is protected by the stinging cells on the tentacles of the sea anemone, while the latter gets to move about, with consequent greater access to food.

There may be one or more even up to four sea anemones on the hermit crab's shell. This number depends on the frequency of predators such as octopuses.

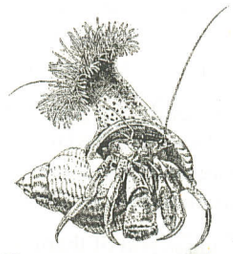


Fig.189 **A hermit crab with a sea anemone on its shell home**

In the absence of these, the hermit crab may not carry any sea anemone, while in areas with large octopus populations, the number of sea anemones on a hermit crab's shell increases. The hermit crab goes in search of a suitable sea anemone and, on finding one, induces it to let go of the rock on which the sea anemone is attached. It does this by massaging the sea anemone, by tapping, rubbing or pulling it off, and then placing it on its shell and holding it till it reattaches. Rarely, the sea anemone makes the first move and transfers itself to the shell with no aid from the hermit crab. The sea anemones are placed in such a position that the overall balance of the hermit crab and its shell is maintained, but in areas infested with octopuses there is a tendency to keep the sea anemone near the shell opening, where it will deter an octopus.

It has been seen that a hermit crab without its protective sea anemone will be attacked and extracted by an octopus. On encountering a hermit crab protected by a sea anemone, an octopus, on being stung by the latter, will retreat as if hurt. After several such encounters, an octopus will even back away when a hermit crab approaches it.

In some hermit crab-sea anemone associations, a young hermit crab places a sea anemone on its snail shell. As the hermit crab grows, the sea anemone secretes a chitinous membrane, called carcinoecium, over the shell, thus extending the lip of the shell. Thus the hermit crab does not have to change to larger snail shells as it grows. The artificial "shell" made by the sea anemone is, however, not large enough to cover the entire abdomen, so that it is prone to an octopus's attack. Some other hermit crabs plant a hydroid colony over their shells. The hydroids slowly dissolve the shell so that, in due course, the hermit crab is covered only with hydroids. These grow profusely and cover the hermit crab, so that it is adequately protected.

Fig.190 **A hermit crab protected by hydroids growing on its "house"**

One family of hermit crabs, the Coenobitidae, have successfully invaded dry land. They may be found far from the shore, but occasionally make mass migrations to the sea to mate, after which the females enter the sea to let the larvae inside the eggs to hatch out and swim away. These *Coenobita* are aggressive, and will attack hermit crabs of other species, sometimes even entering water to intimidate or even kill a hermit crab to occupy its snail shell. But they do not feed on a dead hermit crab–either their own or another species, preferring to eat mangrove leaves, coconut husk and even fish. At Pitti Island in the Lakshadweep, they kill and feed on young terns.

23 Give a dog an ill name—and hang him

India is fortunate in having one of the rarest, and biggest, "crabs"the coconut crab, also called robber crab. It is found on South Sentinel Island of the Andaman Islands group, and also at Galathea Bay in the Nicobar Islands. These are the northernmost haunts of the coconut crab in the Indian Ocean; it is found there from some islands of East Africa (e.g. Aldabra, Cousin Island) to the central Pacific as far as the Gambier Islands in the Taumotu Archipelago and northward to Taiwan and Ryu Kyu Islands of Japan, but is absent in western Indonesia and Malayan Peninsula. Earlier, these crabs were quite common all over the Pacific and Indian Oceans, but they seem to be very sensitive to the presence of man. Wherever a new human settlement springs up, the coconut crab tends to vanish.

The coconut crab (*Birgus latro*) is not a true crab, but a hermit crab. Typical hermit crabs have their abdomen soft and twisted to one side, and this is tucked inside an empty snail's shell for protection. The coconut crab has its abdomen shielded by hard plates and is straight. This is good for the animal; where could it find a snail shell large enough to tuck its abdomen in? The female shows asymmetry in that its abdominal appendages, which carry the eggs, are present only on the left side.

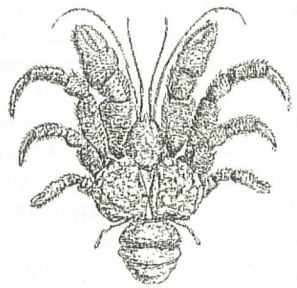


Fig.191 **Coconut hermit crab**

Its body is up to 30 cm long and 20 cm wide and weighs 3 to 5 kg. [But Vogel & Kent (1970) state its maximum weight to be 15 kg.] The span of the legs of a large specimen may be 190 cm, with the girth of the large claw at.20 cm. The left claw is usually the bigger of the two. Its 14 pairs of gills have shrivelled up, and the lining of the gill-chamber is spongy and with warts, so that it can live most of its life on dry land.

The coconut crab, though not named as such by him, seems to have been first noted by Clusius, a French botanist and medical doctor and Professor of Botany at Leiden, in 1605. In his "Ten books on exotic Animals, Plants, Spices, and other strange Fruits". He describes "crabs grazing on herbs from the island of *Tarnate Inter Iavam et Moluccas* (today's Ternate). The translation from Latin reads: On the deserted island at which Francis Drake and his companions had called for fresh water (Ternate) they went into the dense forest and met with many large crabs which were grazing on weeds and plants (gramen). These were hiding themselves in the hollow caves of trees overturned by the wind or even under the trees proper. The seafarers stilled their hunger, which had tortured them for many days, by feeding on the boiled crabs. They thought that, contrary to the habit of other crabs, these large crustaceans could live in dry habitats. After they had taken many of these crabs to the beach and thrown them into the water, they observed that these animals suddenly fled away and made their way back to their pastures".

The next record is by Dampier in 1688, from the Christmas Island. He said that "the robber crab occurs abundantly and equally all over this island. It is even plentiful on the hills of the island plateau, and in some cases it is separated from the sea by three or four miles of jagged limestone pinnacles".

Rumphius recorded it in 1705 from Amboyna. Darwin, during his historic voyage on the *Beagle* in 1836 also mentioned its occurrence in the Cocos-Keeling Islands. And the following reference by Francis Fletcher of Drake's voyage on the *Golden Hind* round the world from an uninhabited island south of Celebes, must surely be of the coconut crab: ".... the huge multitude of a certain kind of crayfish, of such size that one was sufficient to satisfy four hungry men at a dinner, being a very good and restorative meat ... They are, as far as we could perceive, utter strangers to the sea, being always on the land where they work themselves earths, as do the conies, or rather, they dig great and huge caves under the roots of the most huge and monstrous trees, where they lodge by companies together. Of the same sort and kind we found some that when we came to take them, did climb up into trees".

Fig.192 **Coconut crab with its food**

The other name of this creature, viz. robber crab, is based on tales that it climbs coconut trees to steal coconuts and feed on them. (The Latin word *latro*, used in the coconut crab's scientific name, means, "robber".) I have never seen one feeding on coconuts on the ground on its own, let alone on a tree, so it is a question of giving a dog an ill name to hang him. South Sentinel Island has only six coconut trees, surely not enough to feed its population of about 3,000 coconut crabs. But below these trees can be seen broken coconut shells, with the fibrous husk torn from the hard shell. But a coconut crab has enough gripping and cushing power to break a coconut shell, and enough manipulating refineness to dehusk the fibrous layer. When offered a coconut, it hammers open a coconut by thrusting a finger of its large claw into one of the three "eye" holes, and then extracts the tender copra with the small hinder pair of claws. When Alcock visited South Sentinel Island in 1889, there were no coconut trees on it, but he did see coconut crabs there. In spite of their name, the bulk of their diet consists of the fruits of wild chikoo (sapota), and they also relish the fruits of screwpine (*Pandanus*), sago palm (*Arenga listeri*), jackfruit (*Artocarpus heterophylla*), *Barringtonia* sp. and *Canarium* sp. It may sound disgusting, but they are not averse to consuming (human) stools. They also feed on their smaller cousins the hermit crabs (*Coenobita*) and land crabs (*Cardisoma hirtipes, Geograpsus grayi* and *Pelocarcinus humei*) all of which abound on the island. And they do not mind resorting to cannibalism, feeding on smaller coconut crabs.

Coconut crabs are supposed to be nocturnal, but on South Sentinel Island they move about even during the day. This is because the dense forest of the 40-metre tall Andaman bulletwood (*Manikara littoralis*) trees with their many canopies of branches cuts off most of the sunlight, and the gloomy half-light makes the crabs feel at home. The island, barely eight kilometres in circumference, is only a flat coral reef island rising a few feet above sea level, with a lagoon along half of the shore, the rest being rocks or sandy beach.

Loose coral is strewn all over; further up the beach is a belt of screwpine (*Pandanus*) and then starts the forest, but there is no undergrowth, so that one can walk with ease. The island is uninhabited (by humans); apart from coconut crabs, hermit crabs and land crabs, there are the giant water monitors (*Varanus salvator*), growing to 1¼ metres and weighing up to 4.5 kg. Sea turtles visit the island to lay eggs in the beach.

The coconut crabs shelter under the buttress roots and inside hollow logs of the trees. They can walk forward, sideways or backwards equally well, but prefer the forward gait. Movement is, however, clumsy; only the two large pairs of legs seem to be used for walking, the much smaller third pair only helping to keep the abdomen off the ground. They prefer to walk backwards when carrying any object.

While walking on the forest floor is cumbersome for the coconut crabs, climbing coconut trees is no problem for them. To climb, it grasps the tree by entwining its first two pairs of walking legs around it. These legs have just the right curvature to give a firm grip, while the smaller third pair of legs and the massive claws serve as counter-weights. When coming down the tree, the claws are used as brakes, to prevent the crab from hurtling down. They usually climb to 2 or 3 metres, but Rumphius has seem them 30 metres high at Christmas Island, feeding on the fruits of sago palm. If a coconut crab while negotiating a narrow branch slips to the lower side of the branch, it continues upside down, somewhat like a sloth. On some islands, the natives on seeing a coconut crab on the top of a tree, tie a ring of grass high up on the trunk. As the crab comes down, its legs feel the grass and it thinks that it has reached the ground and lets go of the tree, hurtling down to its doom.

Coconut crabs from Amboyna have a predominantly yellow, orange-red, brown and black colouration, only a faint shimmer of blue showing on the limbs. But South Sentinel's coconut crabs have an intense blue with only the ridges and tubercles on the body being bright reddish-orange. The eyes are a beautiful ruby red.

Even the mating of coconut crabs takes place on land. The only time when they have to visit the sea, apart from occasional visits to moisten their gill-chambers, is when females carrying developed young within the eggs go in to shed them. Their larval life is passed drifting in the water.

They are surprisingly docile. When caught, they offer only a feeble resistance, not using their massive claws but only striking out with their powerful second pair of legs. And they are terribly inquisitive, coming right down to the campsite tents, and taking away cans of food, camera bags and sundry items, while not being afraid even of the hot glowing embers of the cooking fire. (No wonder, their other name is robber crab!) And they cannot be frightened by shouting, clapping hands or stamping the ground.

But their strength should not be underestimated. It can lift weights of over 28 kg. Prising away a coconut crab clinging tightly to a tree requires a force of over 30 kg. Rumphius reported in 1705 that a coconut crab tied to a bar on board his ship, lifted a goat passing by clear off the deck. And it can easily support its own weight by one claw –that means 5 kg of lifting capacity. Quite a few examples of its strength are known. A person carelessly got his finger caught in a coconut crab's claw, and it was so badly crushed that the nail came off. Another had the butt of his gun deeply dented by the claws, while a screwdriver held in front of a coconut crab was easily bent.

A coconut crab kept under a galvanized iron bucket with a 20 kg weight on top easily lifted both and tore a nylon tent to shreds. Another crab tied to a peg with strong polythene cord cut it. One claw held the rope taut while the other moved it to and fro in a sawing motion to sever the threads. Yet another crab kept inside a metal bucket with tight-fitting lid which was further tied down by nylon cord, dexterously managed to squeeze the tips of its legs between bucket and lid, tore the cord apart and wriggled out. To add insult to injury it bent the circular rim of the bucket into an oval shape.

When fighting among themselves, the claws are raised to form a protective shield in front of the body. The first pair of legs are lifted high up and, while out of reach of the

opponent's claws, are deftly lowered, trying to pierce the soft, vulnerable joints of the opponent's legs and claws with the sharp tips of the legs. If suddenly approached, a coconut crab will lift its walking legs and point them at the intruder.

Man, as usual, plays a role in their destruction. Natives eat it wherever it is found; its taste is considered pleasing, being a mixture of nuts and goose liver. The abdominal fatty juice (hepatopancreas) is supposed to be an aphrodisiac, and even dried coconut crabs are exported (not from India) to Hongkong. But Baguis (1970) has warned that the hepatopancreas of these crabs, after feeding on the plants *Diospyros maritima* and *Ceodos umbraculifera*, can be lethal if eaten by us.

I had gone to the Andaman Islands on a serious mission, but all cruises have their share of fun and laughs. We were on an Indian Navy minesweeper. Half way between Madras and Port Blair, the sea was as calm and flat as a mill pond, and the captain felt that this was too good an opportunity to be missed. The ship was stopped, and those inclined to have a swim were invited to jump in. But due precautions were taken. Two lifeboats were lowered into the sea, along with a long stretch of net. In each boat was a sailor with a rifle; this was to deter any inquisitive shark from venturing too close. Another sailor, wearing a bathing suit, had a lifebuoy in case any swimmer got into difficulty. The lifeboats took up position away from the ship, with the net stretched between them so as to form three sides of a rectangle; the ship formed the fourth side.

We all went to the lowest deck and jumped in. But one of us climbed to the highest deck, shouted like Tarzan, waved his arms like a hero and jumped in. From the way he struggled in the water, it was obvious that he was no expert swimmer. A sailor from the lifeboat dived in and brought him out. The captain was furious, as he was responsible for the safety and well-being of everyone on board. He gave the chap a dressing down, saying, "Are you such an expert swimmer that you had to go to the top deck to jump in?" As innocent as a lamb, the rescued person replied, "Does one have to learn swimming? I thought that the moment one jumps in, he can swim like a fish".

24 Masquerade (when a crab is *not* a crab)

For I have friends who dwell by the coast,
Pleasant friends they are to me!
It is when I'm with them I wonder most
That anyone likes the sea.
Lewis Carroll

William Shakespeare may have said, "What's in a name? A rose by any other name would smell as sweet." But biologists are more particular in dotting their i's and crossing their t's, and are unhappy when animals are called inappropriate names. Thus there are many so-called "crabs" which are only distantly related to the true crabs (Brachyura).

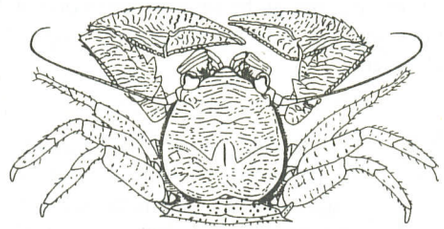


Fig.193 **A porcelain crab**

One such is the porcelain crab, a representative of which–*Petrolisthes bosci*– is common on our shores. It is doubly misnamed. Firstly, it is not a crab but is related to the hermit crabs (Anomura), though superficially it looks more like a true crab. Coloured a pretty crimson speckled with innumerable, short creamy white lines, it has a flat body and huge, flattened claws which also give it its other name– broad-clawed crab. The abdomen is tucked under its body, giving the animal a crabby appearance, but, unlike in a true crab where it is so tightly stuck to the body that some force is required to extend it, in the porcelain crab it is quite loose and can be readily extended. They can also be distinguished as they have only three pairs of walking legs, whereas true crabs have four. Here the fourth pair are slender rods tucked closely against the sides of the body.

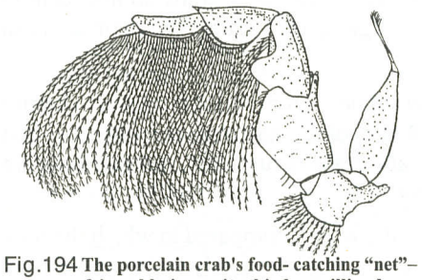


Fig.194 **The porcelain crab's food- catching "net"– fringed hairs on its third maxillipeds**

The antennae (feelers) are very long. It may rightly be named a "brittle crab", as the legs and claws are readily shed at the slightest handling, so that most of them are found with one or more legs or claw missing.

While crabs are scavengers, porcelain crabs feed on tiny plankton by spreading out their third maxillipeds (foot-jaws) which have a dense fringe of long, plumose hairs serving as a net to trap the plankton.

In case one wonders why it is called a porcelain crab, this name comes from a related genus, *Porcellana*. The true porcelain crabs which, incidentally, are Brachyurans, are the tiny ones of a size between a pea and a marble, found on mudflats, whose body has the ivory grey colour and texture or porcelain (e.g. *Philyra*). But, as the name porcelain crab is commonly used for *Petrolisthes* and *Porcellana*,

these (*Philyra*) are beter called pebble crabs, which more aptly describes their size and shape.

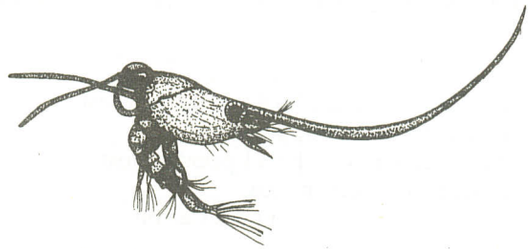


Fig.195 **Zoaea larva of porcelain crab**

The larvae (young) of porcelain crabs are zoaeae (just as in true crabs), but can be readily distinguished by their extraordinarily long rostral and dorsal spines.

Another misnomer is the mole crab (*Emerita, Hippa*). They are very common on sandy beaches all along the east coast of India, though they also occur at Ratnagiri. The term "mole" truly describes its habit of burrowing rapidly. Like a child (or dog) resenting being bathed, they seem not to like water. It is amusing, when the tide is coming in, to see hundreds of them popping out on the sand as the outgoing swash exposes, for a moment, the wet sand. But the next incoming wave sends them digging helter-skelter into the sand as if in a hurry to avoid getting wet. It reminds me of the saying, "each one on his own and the devil take the hindmost". About 4 cm long, their narrow body is shaped like a spindle, with the abdomen loosely tucked under it.

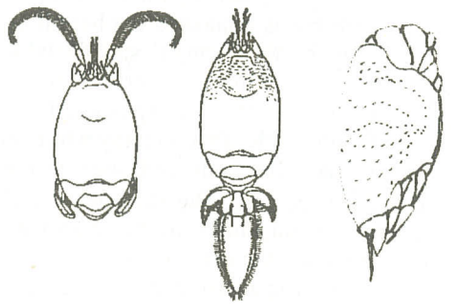


Fig.196 **A mole crab**

The first pair of feelers (antenules) are held close to each other to form a respiratory tube, while the second pair (antennae) are very hairy, looking somewhat like long handlebar moustaches. The tiny eyes, at the end of long thin stalks, look like miniature matchsticks. The legs are hairy and are highly efficient digging shovels; the first pair are the longest. The tail (telson) is long and lance-shaped, but is normally tucked under the body.

The males are less than half the size of the females. And mole crabs do not seem to observe family planning; in the breding season, digging up a square metre of sand can yield enough of the young to fill a small bottle.

Yet other misnomers are the coconut– or robber– crab, which is related to hermit crabs, and the king– or horseshoe-crab, which is evolutionarily nearer to spiders and scorpions (Arachnida) than to lobsters, prawns and crabs (Crustacea). As both these are highly interesting, they will be treated separately.

The coconut crab is the largest "crab" in the world, compared to which the rock crab (*Scylla serrata*) is a puny 15 cm wide. In India, it is found only on South Sentinel Island of the Andaman Is. group and at Galathea Bay in the Nicobar Islands. Like the porcelain crab it too is doubly misnamed. Coconuts are not its normal diet nor does it "rob" coconuts from trees. But it can climb up coconut trees; this ability was noted by the Arab merchant Soleyman as early as the 9th century.

It is extremely shy and, though it is encountered during the day on Sentinel Island it is because this island is so thickly forested that the canopy of branches and foliage allows very little sunlight to penetrate into the gloom. In the Nicobar Is., it passes the day sitting quietly among and between the buttressed roots or in the hollows of fallen tree trunks, venturing out only at night except on very cloudy or rainy days. It goes into hiding even on moonlit nights.

Our coconut crabs have an intense blue body tinge, but the tubercles and ridges on the body may be bright reddish-orange, and the eyes a beautiful ruby-red. Unlike other crabs which often "bleach" (i.e. the body colour fades) when in bright sunlight, coconut crabs, even when taken out to the dazzling white coral sand on the island's periphery, retained the intensity of their colour. However, coconut crabs from Amboyna have their bodies predominantly yellow, orange-red, and sometimes even brown or black, with only a faint shimmer of blue on their legs and claws. The blue tinge of our crabs seems to be peculiar to our region, as colour photographs of coconut crabs from Aldabra (Seychelles) do not show any blue tinge.

Its propensity to climb coconut trees seems to be very rare, as hardly anyone has seen it up such a tree. Even the natives of Nicobar Is. do not believe that it feeds on coconuts. The damage to coconuts is often attributed to the crabs, but the real culprits are often rats. But the pile of broken coconut shells as well as husk below the six coconut trees on South Sentinel Island leads to a strong suspicion that these were made by coconut crabs, and not by rats or monitor lizards (*Varanus*). A crab which broke its tether and climbed up a nearby coconut tree at night remained there for the whole of the next day, dropping down to the ground the next night and hurrying off to a boulder on the seashore. The tender shoots of the palm tree were found to have been cut (and probably eaten), but none of the coconuts had been touched.

Walking on the ground for the crab is clumsy. The first two pairs of walking legs are used, while the small third pair lift the abdomen off the ground. Unlike true crabs, coconut crabs can walk (or rather shuffle) forward, backwards or sideways, but they prefer to walk forward, except when carrying things, when they go into reverse gear. Digging holes for shelter is done by scooping the soil by the smaller right claw, conveying it to the larger left claw, which then shoves it away to the left of its body to form a 10 cm high pile. After finishing its digging, the crab turns around, backing into the pit and hiding its abdomen– sometimes its whole body– into the hole.

The claws are too big to be used as "hands" while feeding, as the large claw cannot reach the mouth. The claws pass the food morsel to the third maxillipeds (foot-jaws) just outside the mouth which, in turn, convey it to the inner mouth parts.

The coconut crab is highly vulnerable; it is on Schedule I of the Indian Wildlife Protection Act, 1972 and killing one is punishable with six months' jail sentence. But, in the good old days before the Act came into force, Dr Robert Grubh, Rex Pimento and others had visited Sentinel Island and even brought two live coconut crabs, which lived in captivity for a few months. In the beginning, feeding them was thought to be a problem, but they thrived on cooked rice, chapatis, coconut kernel, chikoos (sapota), lizards, sparrows and meat.

As we are on the subject of Anomuran creatures masquerading as something else, let us now turn to another anomuran mistakenly named a shrimp.

This is the ghost-shrimp (*Upogebia* and *Callianassa*). It is mistaken for a shrimp as it has a long abdomen ending in a shrimp-like telson (tail). It has a thin and delicate pinkish or creamy white shell, and rather small eyes. It burrows to a depth of 20 to 30 cm in sandy mud in estuarine regions, and also among the small bunds (dykes) separating paddy fields near the estuary. When dug out, it flaps its abdomen and burrows quickly back into the mud, using its second and third pairs of legs as shovels.

Its body is quite hairy; the hairs–especially of the abdominal swimmerets–creating a current of water in the burrow for breathing, as well as for obtaining food, keeping the body clean of mud, and are also sensitive to touch. The claws are unequal in size, the left one usually being the larger.

Food particles are sifted out of the mud, using the hairs, and the discarded sandy mud is pushed up to the mouth of the burrow and thrown out at high tide when the burrow is covered with water.

25 The Bottom Gang

True crabs and blue crabs, land crabs and sand crabs, mock crabs and rock crabs, giant crabs and pygmy crabs; there are crabs and crabs on the seashore.

Crabs, together with lobsters and prawns, comprise the Decapoda or ten-footed animals. All these are a sub-group within the Crustacea.

The process of moulting, or ecdysis, has already been described in an earlier chapter (*The Motley Crowd*). But you might wonder how they can get their legs and claws out through the small joints of the old shell. The legs and body are hinged like suits of armour but, in the joints between hard sections, the outer shell is thin, soft and pliable to allow for movement.

During the moult, the old shell splits open, usually between the large, shield-shaped back (carapace) and the segmented abdomen. After contracting its leg muscles, the crab pulls its walking legs through the smaller joints of the leg exoskeleton (outer shell). Extraction of the claws may require a different process. In crabs with claws much larger than the joint where they attach to the body, the claw is made smaller and softer by a partial breakdown of muscle. Additionally, the claw skeleton splits open if calcium carbonate salts from sections of the claw skeleton are reabsorbed by the muscle tissue. If the muscle does not soften enough or if the shell does not split open, the claw is cast off with the old shell.

The new shell is formed under the old one prior to the moult. Initially it is soft and rubbery. The crab drinks water, stretching the soft shell so that it will be larger than the old one when it hardens. The shell hardens by taking up calcium salts that were stored in the crab prior to the moult reabsorption process. Many crabs eat the old discarded shell as their first meal after moulting. This helps conserve calcium salts.

If you turn a crab over on its back, you can see the flap-like abdomen tucked tightly onto the shell. You can distinguish the crab's sex from the shape of its abdomen. In an adult male, it is a narrow, triangular flap, whereas the female has a round watchglass-shaped abdomen covering all the space between the legs. If you lift up this flap, you will notice four pairs of feathery appendages in the female. The long hairs on these help to carry the tens of thousands of minute yellow eggs.

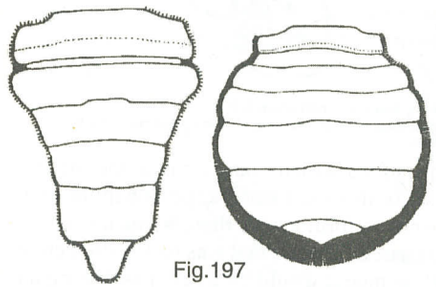


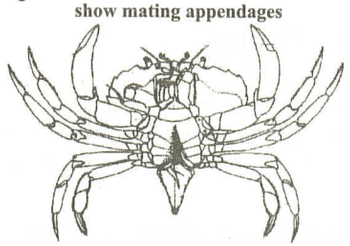
Fig.197

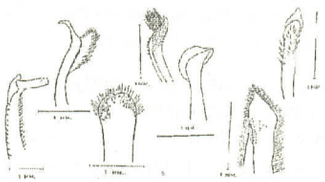
Abdomen of (left) male & (right) female crab

The female carries the eggs for the few weeks while the young are growing inside. The young use up the yellow yolk for food, and the eggs gradually turn brownish black. As the female carries the eggs, the abdomen (normally tucked under her body so as to be invisible from above) opens out horizontally to accommodate the eggs. The crab is now said to be berried or 'in berry', the berry referring to the mass of eggs. Finally the egg shells burst and the young ones come out to drift helplessly in the sea while they grow.

Under the abdominal flap of a male crab are two pairs of rod-like abdominal

Fig.198 **Male abdomen extended to show mating appendages**





Tips of mating appendages of some male crabs

appendages. These are used while mating. Their tips are different in each kind of crab, hence biologists study these to identify crabs that otherwise look alike. As a part of my M.Sc. thesis on crabs, I had prepared a paper titled 'Studies on the Mating Appendages of the Crabs of Bombay State'. Our typist inadvertently (or was it mischievously?) substituted 'a' for 'c', and the paper became 'Studies on the Mating Appendages of the *Arabs* of Bombay State'. Had I not noticed the error it could well have led to diplomatic wrangles with India!

Unlike us humans, where the baby resembles adults except that it is small, the babies (called larvae) of crabs look very different from the adults. From the egg hatches out what is known as a zoaea. It is a couple of millimetres long and has a comic appearance, with a helmet-like head on top of which is a long, tapering spine looking like a dunce's cap, with another long spine in front looking like a comic nose. The body is long and slender. After casting its skin and growing larger at each moult (there are two, four or five moults in different crabs), the zoaea changes into a megalopa. This has a transparent, crab-like body, ten legs and a long abdomen held out horizontally. This, in turn, moults into a young crab.

Fig.199 **Zoaea**

If you hold a crab by its leg, you will probably be left with the leg in your hand. Or when a crab pinches your finger with its claw and you try to shake it off, the crab will drop to the ground, leaving a detached claw still pinching you. This propensity of voluntarily breaking off a limb is called autotomy and is similar to a lizard breaking off part of its tail. The break is not random; at the base of each limb is a 'breaking place' where the crab can snap it off at will.

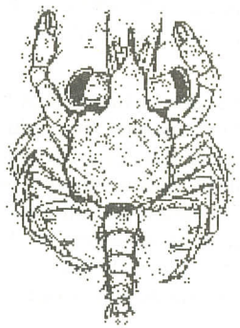


Fig.200 **Megalopa**

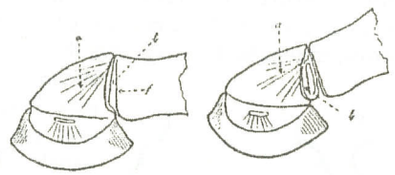


Fig.201

Diagram to illustrate breaking plane of Crustacean limb; a, muscle responsible for breaking; b, detached ring of third segment of limb; f, breaking furrow (After Paul)

After the limb is shed, a membrane forms at the site and prevents bleeding. And the crab is none the worse for its loss; a small knob or papilla soon appears at the stump and, at the next moult, expands to form a new, though much smaller, limb. A couple of moults later, the new limb is as large as the one that was lost. I often envy crabs for their ability to regenerate lost limbs. How nice it would be if, after smashing an arm or leg in an accident, we could break it off and grow a new one!

I mentioned earlier that a crab belongs to the Decapoda (ten legged animals), but you will be looking in vain for ten legs. The first pair is modified to form claws or nippers, leaving only four pairs of legs. And all crabs (with one exception) walk

sideways. The four legs on one side push the body, and those on the other side pull in synchronisation.

Incidentally, a crab's claws are very strong. Each claw can support a weight thirty times the crab's body weight; by comparison, our hand is capable of pulling only two-thirds of our body weight.

The eyes of crabs are borne on the tips of stalks, and are compound, i.e., hundreds of small eyes are grouped together, yet acting as a unit.

Most crabs are scavengers, feeding on carrion, but many can catch fast moving prey, including fish. Many spider crabs are vegetarian.

Fig.202 **Box crab**

The Box Crab (*Calappa lophos*) is rarely seen; most of the time it lies buried in sand with only the eyes protruding. The body is dome-shaped and sand-coloured, streaked and mottled with red. One feature you cannot fail to notice is the large, flat claws with crests like a cock's comb. When disturbed, it covers its front with these claws, thus earning it the additional sobriquet 'shame-faced crab'. The undersides of the body are hollow and vaulted, and the legs can be tucked in for protection. If you dig it out of the sand, it will sidle away and then, right before your eyes, disappear in the sand. That is why it is sometimes called a mole crab. (But it should not be confused with the mole crab *Hippa*, which is not a crab.) While resting, it holds its claws in front of its body. The spines on the claws and the hairy margin of the body form a strainer, preventing sand grains from being sucked into the gill-chambers.

Fig.203 **Claw of box crab**

If you look carefully, the two claws are dissimilar. The larger claw has a knob near the base of the finger, and when the fingers are closed, this fits into a socket on the thumb. The box crab feeds on top shells (*Trochus*), and when it comes across one, manoeuvres it with its walking legs until the shell opening is opposite. Now it breaks the shell mouth with its claw, like a nutcracker or, rather, like a tin-opener, with the tubercle acting like a lever against the edge of the snail shell. If the snail has closed its shell-mouth with the operculum, the crab snips past the closed edge. Now the snail retreats further inside its shell, and the crab follows by peeling along the whorls, until the snail can withdraw no further into its shell. The other, pick-shaped claw is now put to work to tear the snail bit by bit and eat the flesh.

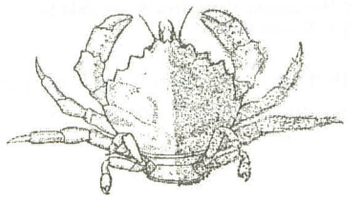


Fig.204 **Sponge crab (hairs on left side removed)**

The sponge-crab or sleeping crab (*Dromia*) has a ball-like hairy body. The first two pairs of its walking legs are normal, but the last two pairs are reduced in size and bent upward over its back, ending in tiny claws. These are used to hold a live sponge over the crab's back. The sponge grows until it covers the body, like a cap. When seen from above, if the crab is sitting still, with its legs folded close to its body, all you see is a

sponge.

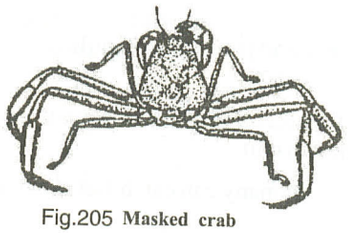


Fig.205 **Masked crab**

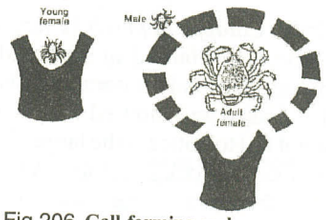


Fig.206 **Gall-forming crab**

The masked crab (*Dorippe*) also has its last two pairs of legs clawed and folded up over its back. But the body is flat. It holds one valve of a dead clam shell over its back for protection. Sometimes, if it cannot get hold of a shell, it even makes do with a mangrove leaf.

Then there is the gall-forming crab (*Hapalocarcinus*), which voluntarily imprisons itself inside a coral branch. When young, it sits in the fork of a branching coral, and by blowing a stream of water from its gill-chambers onto the fork, changes the growth of the coral so that its branches flatten and meet above, enclosing the crab in a pocket or 'gall'. Small openings in the coral allow water to pass through, carrying minute food particles, enabling the crab to breathe and feed.

It is only the female crab that imprisons itself, and this forms the subject of a never-ending war of words between the sexes. (The male crab is much smaller and roams freely in its watery world.) Male chauvinists argue that the selfish female crab enjoys security and protection from enemies within its comfortable castle, leaving the poor male to fight the battles of the world unaided. Protagonists of the fair sex disagree; they say the crafty male encourages his wife to lock herself away from the world, while he is free to go gallivanting, unhampered by family ties or the responsibility of bringing up their children. And while we humans debate, sometimes earnestly and sometimes heatedly, the male crab visits the imprisoned female, apparently to see that no harm has befallen her.

Is it a coincidence that after every visit she is in the family way and sets forth her babies out into the water?

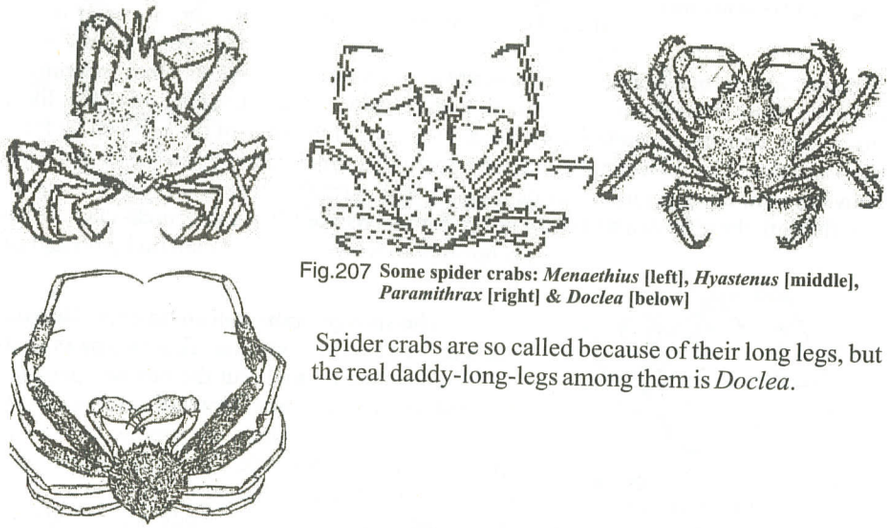


Fig.207 **Some spider crabs: *Menaethius* [left], *Hyastenus* [middle], *Paramithrax* [right] & *Doclea* [below]**

Spider crabs are so called because of their long legs, but the real daddy-long-legs among them is *Doclea*.

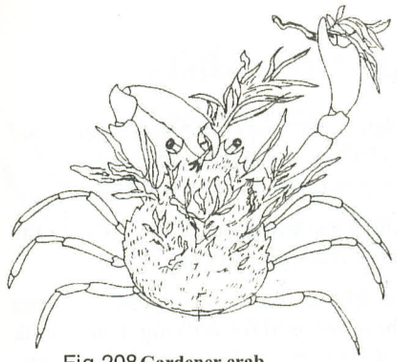


Fig.208 **Gardener crab**

The gardener crab, *Paramithrax* (also a spider crab), has several long spines on its back. It adorns itself by planting seaweeds, sponges, zoophytes and polyzoa on its back. This is an ideal camouflage so long as the crab keeps still. I have often been intrigued to see a clump of seaweeds moving briskly, until I realised that it was in reality a gardener crab with its heavy make-up.

Many animals which are familiar to fishermen and local gourmets often turn out to be very interesting and important to scientists. Thus the largest crab in the world, a spider crab called *Macrocheira kempferi*, became known to westerners only in the 18th century. Engelbert Kempfer was a German physician employed by the Dutch East India Company. He visited Japan in 1690-92 and wrote a book, *The History of Japan*, which contains descriptions of many marine animals. This book was published posthumously in1727.

This spider crab attains an astonishing span of 3 metres across its outstretched claws. Kempfer illustrates only one of the joints of the crab's claw, which he bought at a restaurant in Suruga, in the form of a cooked delicacy! He has graphically described it as being the size of the bone in a man's leg.

I remember having seen a dried and mounted specimen of this spider crab way back in 1949, at Phipson's wine store, where the museum collections of the Bombay Natural History Society were then housed, and which I used to visit for my postgraduate reference work. I also remember that at 3 p.m., a trolley with huge urns of tea and coffee would be trundled in into the library, and a cup served to those inside. I was embarrassed to have this generosity day after day, so, after a week I told the peon that I was not a member of the Society. The man graciously replied, "Saheb, you may or may not be a member, but it is our burra saheb's desire that whoever was present in the company premises at that time would be offered a cup on the house". I was greatly impressed by the hospitality and changed my time of visit to a later hour to avoid a sense of self-guilt.

26 The Sidewalk Specialists

There are three species of creatures which, when they seem to be going, are coming, and when they are going, seem to be coming. They are: diplomats, women and crabs.
John Hay (With apologies to the first two categories).

Probably the first crabs you encounter will be swimming crabs, as they are the ones sold in fish markets. They are quite large, and many are pretty in colour.

Swimming crabs do not swim all the time. In fact, the first three pairs of legs (behind the large claws) end in pointed tips, and these are used for walking. Crabs walk sideways, with a quick shuffle, as the joints of their legs are like our elbow joints, capable of moving only in one plane. On dry land, their gait is clumsy, though quick, but under water these crabs walk daintily on the tips of the legs. Swimming is also done sideways, the claw in front being folded while the claw at the rear is stretched out.

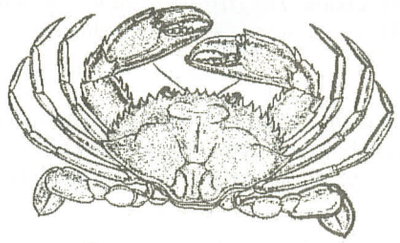


Fig.209 **Mud crab**

The commonest crab encountered in the markets is the Mangrove Swimming Crab or Mud Crab (*Scylla serrata*). It is usually sold at a size of about 8 cm (across the width of the back), but it can grow to a whopping 21 cm, and the claws of a crab of this size can easily break one's finger. Luckily for the gourmet, they are sold with their arms trussed up. They are a drab olive green or earthy brown in colour, and the sides of the body each have nine spines, all of equal size.

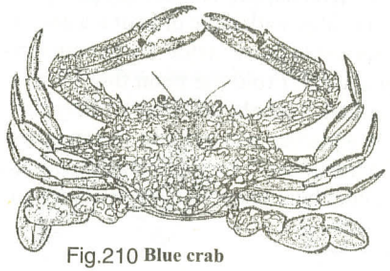


Fig.210 **Blue crab**

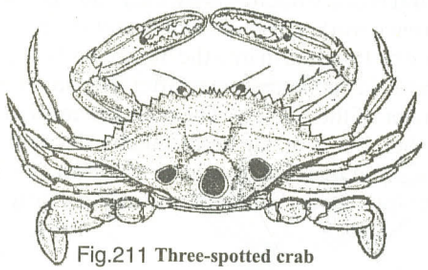


Fig.211 **Three-spotted crab**

Fig.212 **Christ crab**

The Blue Crab (*Portunus pelagicus*) and Three-spotted Crab (*Portunus sanguinolentus*) are some of the prettiest. Both are characterised by having their body curving in a semicircular arc, with nine spines on the border, of which the last is elongated. In the blue crab, the male is much larger than the female, and its body and legs are blue, while the female's body tends to a yellowish grey. Both have white spots scattered all over the body.

Crabs of the genus *Charybdis* have only six spines on the sides of the body, and *Thalamita* have five. An interesting *Charybdis* species is the Christ Crab, which has a design on its back of a cross with, on either side, what looks like an angel with flowing wings.

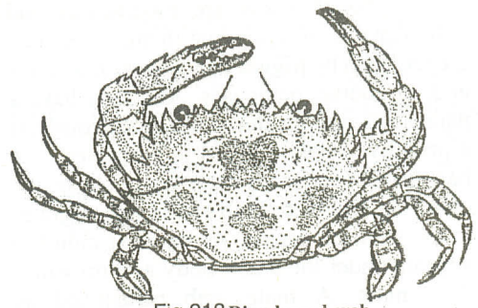


Fig.213 **Ring-legged crab**

One of the most pugnacious swimming crabs is the ring-legged crab (*Charybdis annulata*). I should know because I have been bitten most often by it, and though the crab usually broke off its claw, fell to the ground and ran away, the claw would remain tightly pinching my finger. When accosted, this crab rises on the tips of its legs, spreads it claws upward and forward and clashes them together in a fit of absolute rage. If this does not suffice to deter you, you deserve punishment. Yet another swimming crab is the dainty Calico Crab or Oar-footed Crab, also called Dolly Varden (*Mututa lunaris*). All its legs have flattened paddles, so that, while it can swim easily and gracefully, it cannot walk and is helpless if washed ashore on the beach. The body is yellow with numerous dots or meandering lines and loops. Two long and stout spines are its protection.

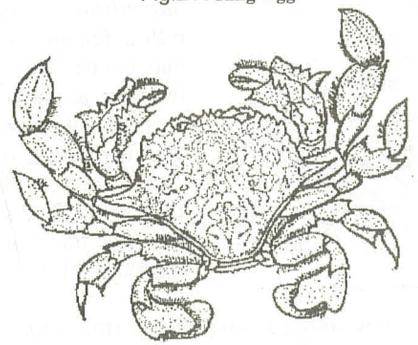


Fig.214 **Oar-footed crab**

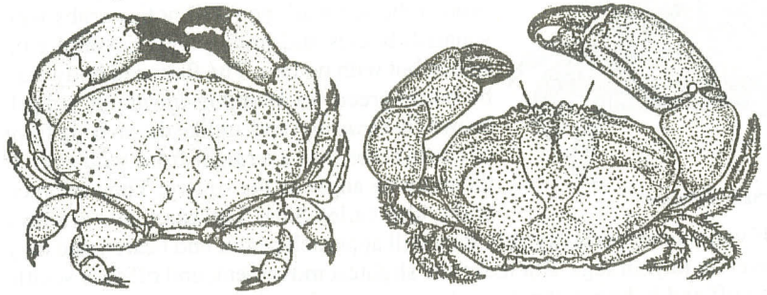


Fig.215 **Bashful crab:** ***Atergatis*** **[left],** ***Ozius rugulosus*** **[right]**

If, as a novice, you want to catch a crab, go for the Bashful Crab (*Atergatis integerrimus*), *Ozius rugulosus* or an *Actaea*. On being picked up, any of these will just fold its legs and claws against its body, and feign death. And how do you catch and hold a crab? First, with your thumbs pressing down on the crab's body, immobilise it so that it cannot escape. Then, carefully bring your forefingers against each claw and force the claws against the front of the body. You can now lift the crab from the ground. Do not worry if the pointed ends of the walking legs try to unnerve you. Alternately, you may hold the crab with the thumb below its belly and the fingers on its back. Watch out, however; many crabs can bring their claws down and pinch your thumb.

One crab has found out a novel way of protecting itself from enemies. It holds a live sea anemone in each claw and, when threatened, waves the claws about. Any enemy that has earlier been stung by a sea anemone knows how much it hurts and therefore keeps away.

Fig.216 **A boxer crab holds a sea anemone in each claw**

Though crabs are pugnacious and quite capable of defending themselves, they are fed upon by trigger fish, box fish, wrasses and, of course, octopuses. And they have a parasite named *Sacculina* which, curiously, is a primitive relation allied to barnacles. The baby parasite attaches itself to a bristle on the crab's leg, enters the crab's body, and migrates to the stomach region. At the next moult, it appears under the crab's body as a brownish mass. A male crab parasitised by *Sacculina* turns into a female. (It may not be able to function as such, but the shape of the abdomen and the sexual appendages resemble those of a female crab.)

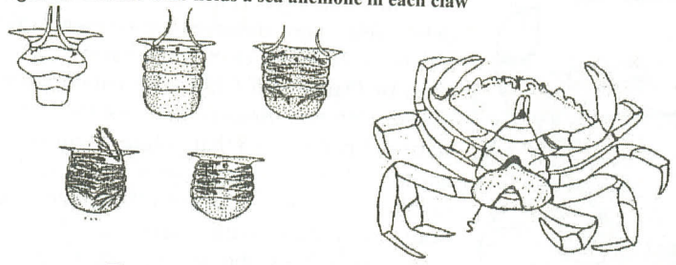


Fig.217 ***Sacculina*** **[right] turns a male crab into a female**

Fig.218 **"Sally lightfoot"**

While taking a stroll on a marina, where boulders and concrete tetrapods are placed to protect the sea wall, you will notice crabs with squarish bodies and prickly legs covered with spines but with no hair. The flattened body may be bottle-green (in *Metopograpsus*) or reddish brown (in *Grapsus*) and, unlike the arching front of shore crabs, has a straight front with eyes at the extreme angle of the square. They are rock crabs, also called Sally Lightfoot, and are very inquisitive. If you remain perfectly still, they will approach nearer and nearer, and may even crawl over on to your legs. But make the slightest movement, and off they scuttle away, dashing off and hiding in the nearest crevice or, if no shelter is nearby, jumping into the sea. Look at their claws and you will see why they did not put up a fight. The claws are puny, shorter than the legs. They may be four to five cm across, and the shell is thin and papery. They scrape off algae for food.

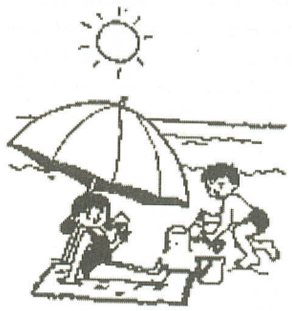
Actually, the light-weight, long-legged crab *Grapsus* probably became known as the Sally Lightfoot because of its agility. The verb "sally" means to leap out and burst forth suddenly, and the noun "sally" refers to troops bursting forth, probably light-footedly, to attack the enemy.

In addition to being a quick mover, this crab effectively uses the last segment of its legs like a rock climber's pitons to climb and cling onto rocks exposed to breaking waves.

Lady Luck seems to have smiled on me again and again, for one of the three new species of crabs which I discovered is a cousin of the rock crabs. While collecting crabs right in the middle of the city, I frequently came across tiny crabs, about a centimetre

wide, and with squarish bodies. For many months I thought them to be juveniles of *Metopograpsus*, and did not even bother to pick them up. One fine day, I lifted a stone from the seashore, and down jumped a small square crab. It landed upside down on its back, and I saw an orange yellow mass of eggs. This meant that it was an adult female, and so it could not be a juvenile rock crab. When I examined it more closely, I found that the legs were hairy (those of rock crabs are thorny), and the claws were more massive than the walking legs. After a detailed study, it turned out that I had discovered another new species!

27 Beach Buddies



Pour'd from the neighbouring strand, deformed to view,
They march a sudden, unexpected crew!
Strong suits of armour round their bodies close,
Which, like thick anvils, blunt the force of blows;
In wheeling marches form'd, oblique they go,
While harpy claw their limbs are arm'd below.
Battle of the Frogs and Mice.

Crabs are well protected by their hard, armour-like shell and have powerful claws so one would expect them to move fearlessly about, hurling defiance at their enemies. On the sandy beaches and mudflats of our seashores, however, what do we find? Timid creatures with a lot of bravado, but no inclination to fight.

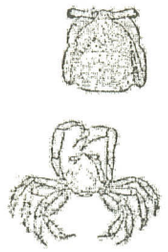


Fig.219
Sand-bubbler crabs

The Sand-bubbler Crabs (*Scopimera, Dotilla*) burrow in sand in sheltered bays. As the tide falls, they emerge from their vertical chimney-like burrows and start feeding. Unlike most crabs which are carnivorous, these feed on the layer of organic matter left on the sand. On emerging, each crab proceeds in a straight line away from the burrow, picking up sand grains, sifting them and scraping off the food, then moulding the sand grains into a round pellet with the help of the mouth appendages and leaving it on the beach. Several such trenches are made radially, with the burrow as the centre from which these radii stretch out in straight lines. The pellets, strung like beads along each radius, make a striking pattern shaped like a sunburst on the beach, and are the hallmarks of these crabs.

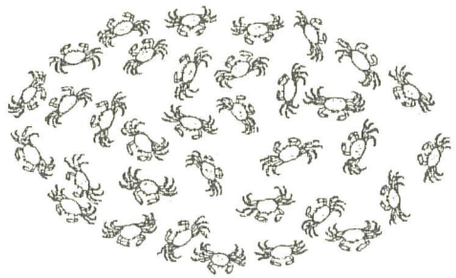


Fig.220 **Soldier crabs**

The flat third joint of each walking leg has a curious, oval, window-like membrane called "tympanum".

Near estuaries with an admixture of mud and sand, we see Soldier Crabs (*Mictyris*). As the tide ebbs, the smooth wet sand shows tiny heaps, as if something buried underneath is pushing it up. Keep absolutely still, and in no time you will see hundreds, even thousands, of tiny, pea-sized, deep-bodied crabs crawling all over the sand.

I met my mates in the morning (and oh, but I am old!)
Where roaring on the ledges the summer ground-swell rolled.
The song of pleasant stations beside the salt lagoons,
The song of blowing squadrons that shuffled down the dunes
I met my mates in the morning (I'll never meet them more!)
They came and went in legions that darkened all the shore.
Rudyard Kipling *LUKANNON*

They are soldier crabs, so called because they move together like an army on parade. They have been described as "marching in formation", now in line, now in mass formation, wheeling and turning like an army at exercises. An army, did I say? Move just a little or stamp your feet, and you will find them beating a hasty retreat, scattering in all direction, each one scrambling for himself and the devil take the hindmost! They behave more like a rabble or horde rather than well-disciplined solders. Finally they get so panic stricken that they disappear like magic in an instant, having burrowed spirally in the sand like a corkscrew.

But, if undisturbed, they will start feeding, moving slowly and stopping here and there on the way. They pick up sand grains with their tiny claws, scrape off organic food-matter from them with the help of their many mouth appendages, which then mould the sand grains into a round pellet that is dropped on the ground. These characteristic pellets show where the soldier crabs have been feeding, as, in the meanwhile, the crabs may have moved off a hundred metres away.

What print of fairy feet is here,
On Neptune's smooth and yellow sands?
What midnight elves in airy dance,
Beneath the moonbeam's trembling glance
Have chased the waves, uncheck'd by fear?
Whoe'er they were, they fled from morn;
For now, all silent and forlorn
These tide-foresaken sands appear.

Sometimes, instead of coming up to the surface, the crabs (usually the females and young) tunnel just under the surface, feeding in these horizontal passages.

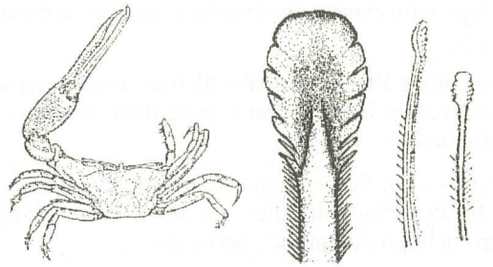


Fig.221 **Male fiddler crabs and detail of spooned feeding hairs**

Fiddler crabs (*Uca*, formerly *Gelasimus*) dwell in large numbers on mud flats with a mixture of sand. They are so named from the huge claw of the males. As in the crabs we read about above, fiddler crabs use their small claw(s) like spoons to pick up sand grains and convey them to their mouth. Fiddler crabs feed at low tide. The small claws scoop up sand and mud and press it towards the mouth. Special setae (hairs) on the second maxillipeds act as strainers, separating the lighter edible organic matter from the heavier mud. Special spoon-tipped setae help further to sort out the two components. Water from the gill chambers washes out the mud particles, which are pressed to form a pellet, which is thrown away. The male has only one such small claw, and is therefore at a handicap while feeding. Its huge other claw is used in courtship to beckon females, and to ward off and fight rival males. In Brazil, the fiddler crab is called “chama-mares”, meaning the one who calls the tides.

Feeding on mud may sound quaint, but I too have had encounters with quaint foods. This happen in the early 1960's when I was participating on cruises during the International Indian Ocean Expedition. I was invited for breakfast on a Norwegian oceanographic ship.

The mess steward placed some slices of steaming hot bread, baked in the ship's oven, followed by several collapsible tubes of the kind used for toothpaste. Each tube had a differently coloured stripe and something written in a Scandinavian language but which was Greek and Latin to me. Now the best way to observe correct table manners and not commit a *faux pas* is to observe what others do. The ship's captain, who was sitting opposite me, noticed my predicament and explained to me that each tube contained sandwich spread of a certain flavour– red for prawns, yellow for cheese, green for spinach and so on. All I had to do was to select the flavour I liked and squeeze the tube of my choice on to the bread slice!

The movement of the huge brightly coloured (cherry red or yellow) claw– the "hand" of the claw alone is larger than the crab's body– reminds one of a fiddler drawing his bow across the strings of a violin, and hence the name. In India, the crab is also called Dhobi Crab, the arching movement of the large claw being likened to a *dhobi* (washerman) bashing clothes on a rock while washing them.

If you observe fiddler crabs in a colony, you will find that roughly half of the males have left large claws, while the other half have large claws on the right side. It was earlier explained away by a belief that when a large claw is lost by accident, the smaller claw grows into a larger one after a moult, while a new small claw develops to replace the lost (large) claw. But it is now known that when a large claw is lost, a new large claw develops on the same side at the next moult. Incidentally, very rarely are the small claws lost or autotomised. Very rarely, a male may have both claws enlarged.

Differentiation into a large and small claws begins at, or soon after, the second post-megalopal stage, but even at this early stage it is not due to the loss of a claw.

Fiddler crabs sometimes carry out "mass drill". All together, they will raise their bodies by standing on the tips of their legs, with claws raised upward, then squat down on the sand and repeat this again and again.

Fiddler crabs make burrows descending almost vertically till they reach water at the bottom. They stand guard at the mouth of the burrow, brandishing their large claw, but they are shy and will go inside as we approach.

All crabs have stalked eyes, but those of fiddler crabs are extremely long and slender, looking very much like matchsticks. Normally they are protected by being lodged in long grooves, but they can pop out like a submarine's periscope.

The Portuguese relish eating fiddler crab meat, but they are good conservationists. Instead of killing them, they catch a male, break off the large claw and release the crab. In due course, at the next moult, the crab will grow another claw. This way the crab population is not depleted, and there is a never-ending supply of claws.

Where conditions are favourable, fiddler crabs abound in large numbers; there may be 30 crabs per square metre.

Fiddler crabs can run quite fast and escape into their burrows. The trick in catching them lies in running around on the beach in a large circle and gradually narrowing the circles. The crabs collect in a heap in the centre of the circle and can be easily gathered.

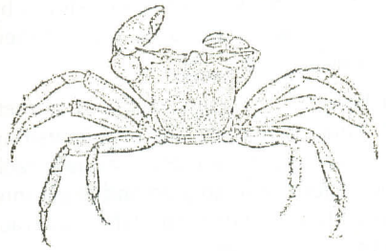


Fig.222 **Ghost crab**

Finally, we come to the Ghost Crabs (*Ocypoda*), which live high up on the sandy beach. They too live in burrows, and the square body is coloured like sand. They run extremely fast on the tips of their legs, casting a shadow of their body on the sand.

All of a sudden they stop, and lower their body so that the shadow disappears. The colour of the body matches the dry sand, and it looks as if the crab has just disappeared and melted away in the sand; hence the name "ghost crab".

Fig.223 **Ghost crab with eyes extended forward**

Both sexes have large claws, but one of the claws is larger than the other. On the inner surface of the "hand" of the larger claw there is a row of fine teeth. Rubbing these against a file-like ridge on the "arm" of the claw produces a creaking noise in the grey ghost crab (*Ocypoda ceratophthalma*) of our west coast (shores of the Arabian Sea). The red ghost crab (*Ocypoda macrocera*) of the east coast (shores of the Bay of Bengal) makes a louder chirping sound like a startled squirrel. This rasping sound is often made by the occupant of a burrow when another ghost crab intrudes into its burrow. (One species, *Ocypoda cordimana*, does not have this "stridulating organ".)

In all ghost crabs but one (*O. cordimana* again), the eyestalks protrude beyond the eyes like long slender horns, the eyes being on the middle of the eyestalks.

Living high up on the foreshore, ghost crabs can live for a long time outside water. The seven pairs of gills are well developed, but the walls of the gill-chambers are lined with skin richly supplied with blood vessels, so that the gill-chambers (as long as they are moist) breathe air which enters them from a slit between the second and third walking legs. The slit can be easily made out as it is fringed with hair. While on a study tour to Tamil Nadu, we once caught a ghost crab and popped it into a jar, intending to add alcohol (to preseve it) when we reached our laboratory. Somehow we forgot to do this, and came back home after a week. On opening the jar, I was surprised to see the crab run away; it had been out of water for a week, but was not affected.

Crabs that live above the shore-line can smell water even a hundred metres away and will head towards the sea even if they cannot see the water. In the rainy season, however, they lose their sense of direction and get confused, as the air is saturated with moisture.

The ghost crab digs a burrow which may go down a metre or more where the sand is moist. If the burrow gets covered with water at high tide, it has to be excavated again at low tide. The crab grabs some sand between two of its legs, carries it to the entrance and throw it away with a jerk, repeating this until it is satisfied. It then presses on the wall of the burrow, using its back and larger claw, to make the sand compact and prevent it from caving in.

Unlike the other beach crabs, the ghost crab is carnivorous and feeds on small crustaceans like isopods or sand-hoppers and insects. It is also a carrion feeder and

helps to clean the beach of waste food left behind by picnickers, or dead fish left by fishermen. Newly hatched baby turtles are a delicacy, and so are turtle eggs. In their turn, ghost crabs are relished by brahminy kites and jackals.

Nowadays, whenever I take a stroll on the beach, I am reminded of cold sherbet. There is an interesting experience behind this. A Rotarian realised that people visiting our beaches have no idea of the rich variety of life on them. He wanted to organise beach trails where visitors would be taken on a conducted tour so as to gain an insight into Nature's fascinating secrets. He gathered a bunch of interested collegians who would act as docents on the trail, and I was asked to train them.

For the inauguration of the beach trail, high profile gentry were invited. I was busy from morning till noon, taking batch after batch of guests and journalists on the beach. Around noon, food was served but was quickly snatched up by the guests, so that the docents and I remained hungry and thirsty. As there was no drinking water in the bungalow, my colleague and I went out into the garden to see if there was water in the taps for watering the lawn. Alas! These too were dry, when my colleague spotted two bottles of water hidden behind a bush. We opened a bottle and washed our hands with it. I noticed some waiters in the garden glaring at us but paid no heed. It was really refreshing to feel the water cooling our arms and hands. More luck was to come, for I saw a bottle with a little lime juice cordial in it. So, instead of drinking plain water from the remaining full bottle, we decided to make lemon sherbet. I got hold of two empty glasses, poured a couple of centimetres of cordial into one, topped it up with water and offered it to my colleague. He took a sip and told me it was bitter. I thought I had put too much cordial, so I took less cordial in my glass and topped it up with water. My first sip made me splutter; the "water" in the bottle was gin! No wonder the waiters were scowling at us. They had hidden the bottles, to enjoy the gin after the guests had left, and we had used it to wash our hands!

28 Gladiators of the Sea

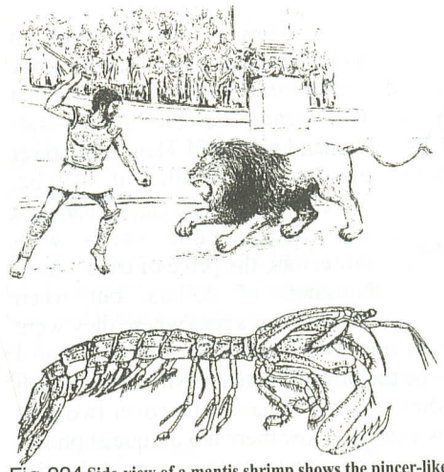


Fig.224 **Side-view of a mantis shrimp shows the pincer-like claws resembling a praying mantis inspect**

How cheerfully he seems to grin,
How neatly spreads his claws,
And welcomes little fishes in
With gently smiling jaws!
Lewis Carroll
ALICE'S ADVENTURES IN WONDERLAND

If you ask me which animal in the sea I would least like to handle, I shall not have to think twice; it is the mantis shrimp. My work on crabs fetched me my master's degree, so it is but natural that I have a soft corner for crabs. Now, large rock crabs (also called mud crabs or mangrove crabs–*Scylla serrata* to scientists) can have claws as thick as one's wrist which can crush or break a finger with ease, yet I handle them with impunity, though also with respect. But, though mantis shrimps got me my doctorate, I would not say that I like them overmuch, and when it comes to catching them, I still take recourse to using forceps or tongs.

Fig.225 **folded [left] and extended [right]**

The name comes from the resemblance of their claws, or rather the way in which they are held, akin to the praying mantis insect. They are folded close to the body in an attitude of prayer, or in the manner of our Indian way of greeting (*namaste*). Like with the praying mantis, they can be shot out with lightning speed to catch prey. The body is short, with three pairs of weak walking legs. It continues into a long "tail" (actually abdomen), on the underside of which are the swimming paddles. Both are armed with sharp ridges and numerous spines which provide a strong deterrent to enemies. The abdomen can be curled under the body, and the strong claws are ever ready for action. If you try to hold a mantis shrimp by its tail, the head will curl under to snap at your fingers, and if you take care to hold it near its front end, the tail will curl under to jab you. Fishermen call them thumb splitters; if they are a bit careless when sorting the fish catch, a mantis shrimp's claws can inflict a nasty cut a centimetre deep.

Fig.226
The conspicuous black-and-yellow warning coloration on a mantis shrimp [Lysiosquilla maculata] (Also see cover)

Fishermen have another reason to hate mantis shrimps. When the number of mantis shrimps in the trawl catch increase, that of prawns declines. Mantis shrimps are edible; their flesh is as delicious as a prawn's, but, while a prawn's thin shell can be easily peeled, that of mantis shrimps is as thick as a lobster's. While they are a delicacy in southeast Asia, our fishermen throw them away.

Most mantis shrimps are about the length of one's finger, and they are abundant throughout the year in trawl catches. But, during the rainy season, two very large species of mantis shrimps appear in large numbers in the fishermen's nets. The larger of these two (*Harpiosquilla raphidea*) was described

by Kemp to be as much as 33.5 cm long. I have collected a specimen of this mantis shrimp exactly as large as Kemp's specimen. Had it been just a couple of millimetres longer, I would have broken the record for collecting the world's largest mantis shrimp. My specimen now reposes in the Prince of Wales Museum, Mumbai.

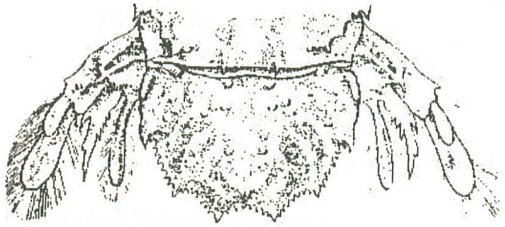


Fig.227 **The tail of *Clorida bombayensis* from Bombay – one of the rarest mantis shrimps in the world. (Only one specimen is known so far)**

How is the price of an article determined? Any commerce student will tell you that it depends on the supply-and-demand principle. Hence, the rarer an item, the costlier it will be. When there were less than ten *gloriamaris* cone shells with collectors, the price of each was in thousands of dollars, but when divers found a reef where they were abundant, the price fell. Our white tigers are so expensive because there are less than a hundred of them in the world. So what should be the price of a mantis shrimp of which only one specimen is known? During my studies, I was fortunate to discover two new species of mantis shrimp, which were not known earlier. Now there is a unique euphoria in finding a new species and realising that you are the first human to recognise this life form as something separate from all others. It's as if you have been privileged to a first showing of a new exhibit in the gallery of life. Anyway, coming back to my two new species; of one of them, I could collect only one specimen, and, so far, no more specimens of this species have been found. Dr. Salim Ali's bat (*Latidens salimalii*) as a new species, was based on only one specimen, hence it gained an entry in Guiness Book of World Records. But, a few years back, eight more specimens of this bat were collected in South India. So, though our scientists were justifiably happy to have more specimens to study, the entry in Guinness' book is no longer valid. (Incidentally, I have not tried to sell my rarest of rare mantis shrimp to the highest bidder. As per zoological ethics, it is lodged with the Zoological Survey of India, Calcutta.)

Mantis shrimps live in tropical and subtropical seas. (They are not found in fresh water.) Mostly burrowing in mud or sand, they can also excavate tunnels under rocks or in coral crevices. They can be grouped into two types, based on the manner of killing their prey. There are spearers, and there are smashers.

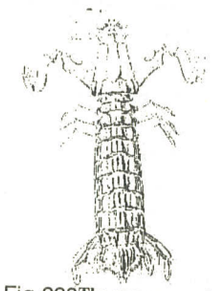


Fig.228 **The spearer mantis shrimp's claws have formidable spines**

The spearers have their flattened claws armed with five to six hooked spines. A mantis shrimp will lie motionless at the mouth of its burrow, with folded arms in the typical attitude of prayer. When its prey soft bodied animals such as prawns, worms or fish, comes within striking range, the arms are shot out at lightning speed to grasp the prey, and then brought back to the mouth, where the prey is chewed and eaten. Scientists who have filmed mantis shrimps say that the claws shoot out at a speed of 1,000 cm per second.

The smashers prefer hard shelled prey. Their claws do not have spines along their edge, but the elbow is swollen into a huge

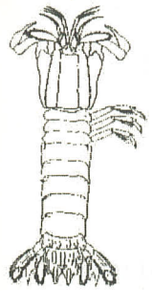


Fig.229 **Smasher mantis shrimp lacks the series of sharp teeth on its claws**

knob, like in an arthritis patient. The mantis shrimp uses it like a hammer to rain blows upon the hard shells of its prey clams, snails and crabs. With repeated blows, which scientists have calculated to have the power of a bullet from a ·22 calibre rifle, the shell is broken, and the mantis shrimp then leisurely feeds on the soft inner parts.

Mercy is not a quality to be expected from mantis shrimps. When establishing a territory, they will often fight to a finish, with the winner devouring the vanquished. Mantis shrimps are equally comfortable upside down on their backs. A mantis shrimp will often lie on its back and coil its abdomen to act as a shield to block the blows of its rival. The tails of smashers have ball-like ends with strong ridges on them. These absorb the blows of the enemy. A few such blows, and the defender thinks that enough is enough. It will uncoil and attack its rival which, in turn, assumes the upside down posture. I have often watched these fights lasting upto fifteen minutes, when one of these may concede defeat and swim away. Unlike lobsters and crabs, mantis shrimps do not carry their eggs attached to the underside of the abdomen but carry the egg mass in their jaws. The larva, called alima, is as fierce as its parents.

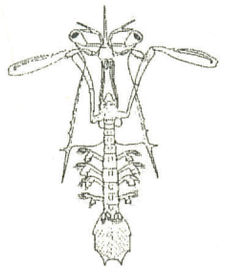


Fig.230 **Alima larva of a mantis shrimp**

Fig.231 **The eyes of different shrimps vary from tiny to huge**

Some mantis shrimps, like the peacock mantis shrimp, have brightly coloured "eye spots" on the tail flaps. The creamy yellow tail has two cobalt blue spots edged with red. Normally, these eye spots are covered by the outer pair of tail flaps, but, like the eye-spots of some butterflies and moths, they can be suddenly displayed to create a, startle effect on would-be predators.

The spiny-tailed mantis shrimp (*Echinosquilla*) has its tail ending in a spiked ball, somewhat like the ones used by mediaeval warriors in battle. When threatened, they enter their burrow head first, blocking its entrance with the sea urchin-like spiky tail to deter its enemy.

Scientists can also make *faux pas* once in a while. An expert on the oceanographic ship R.I.M.S.S. *Investigator* once caught over 500 mantis shrimps. Since there were so many of them, he thought them to be a common species. So he preserved only two specimens, and handed over the rest to the ship's cook, who prepared 'Prawn' curry with them. When the ship returned to base, the scientist examined the two specimens and, to his horror, found that they were a new species. As zoological museums at that time would gladly have paid £.1 for a specimen of the new species, named *Squilla investigatoris*, the prawn (!) curry proved to be one of the most expensive dishes served on the ship!

29 Oddest Ancient Oaf Alive

As a beauty, I am no great star,
Others are handsomer, by far;
But my face–I don't mind it
Because I'm behind it,
It's the folks in front that I jar.

Anthony H. Euwer

If you happened to wade in the shallow sea along the shores of Europe some 200 million years ago, you would have seen a sluggish, armoured creature lumbering along on the sea bottom like an army battle tank. It would have also been, to say the least, very odd, because there were no human beings then!

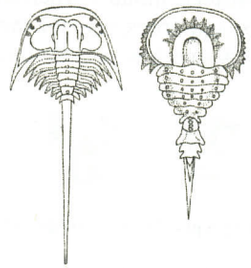


Fig.232 **Two fossil horseshoe crabs**

That creature, or its descendants, are still alive today. Untold millions of years before the mighty dinosaurs reared their heads in the primordial swamps, flourished, dominated their periods, and then became extinct, and while other close relatives finally left the water and became the first land animals, the horseshoe crabs– for these are the animals I am referring to – were seemingly so well adapted to their way of life that no "improvement" was deemed necessary by Mother Nature. That is why they are called "living fossils".

A fossil is anything found in strata (layers) of rocks recognisable as the remains of a plant or animal. Usually, anything buried by natural causes for at least the last 10,000 years and preserved in rocks is called a fossil; remains of life more recent than these are called sub-fossils.

A living fossil is an animal (or plant) that has survived beyond its era. During evolution, an animal– or a group of animals– appears on earth, thrives and multiplies, gives rise to other related species, and then dies. The life of species– like that of individuals– varies in length. Some species, from inconspicuous beginnings, become so successful that they breed rapidly to form large populations and spread across vast portions of the earth. After reaching a pinnacle of success, they decline equally rapidly and become extinct. In other cases, however, an animal takes a long time to reach its peak, but then persists for such long periods that it is still alive today. It's like the story of the race between the hare and the tortoise. The hare-type animals led a gay but short life, while the tortoise-types evolved slowly but are still plodding along.

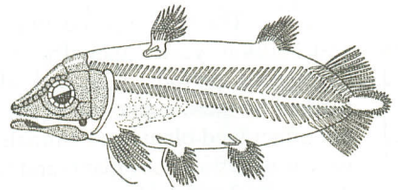


Fig.233 **An ancient Coelacanth fish found as a fossil.**

A classic example of a living fossil is the Coelacanth a fish which had its heyday during the Devonian period (405 million to 345 million years ago) (see explanation below), persisted unchanged for 230 million years, and were supposed to have become extinct during the Upper Cretaceous period, because no fossils were seen in these recent strata. In 1938, a live Coelacanth fish was caught off South Africa, proving that the fish was successful in evolution, lurking in the depths of the sea while paleontologists (people who study fossils) had thought them to be long extinct.

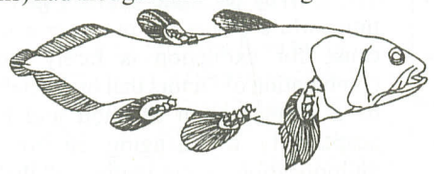


Fig.234 **Present- day Coelacanth fish from Mozambique**

Through natural selection's law you are, as I'm alive,
Of all survivals found, the least fit to survive.

John Powell

Talking of living fossils and Coelacanths reminds me of an amusing experience I had as Curator of the Taraporevala Aquarium. A postgraduate student from an inland university enquired if we at the Aquarium could send him ten live female Coelacanths every month for his research! I wanted to burst out laughing, but had to keep a stern mien as I explained, tongue in cheek, about the rarity of these fishes, the location where they were found, the resources required to obtain them and the consequent expense, apart from the difficulty in sexing them. The student must have thought that I was a wet blanket, putting hurdles in his way, instead of helping him out in pursuing his pet venture.

Life began on earth some 1500 million years ago. During the first 1,000 million years, the earth was undergoing vast changes. New mountains rose, while older ones were levelled, so that there are few fossils found in this period called by geologists the pre-Cambrian period though some jellyfish, lamp-shells and worm tracks have been observed. This was followed by the Cambrian period (600 million to 520 million years ago) where various hard-shelled marine invertebrates are seen. In the next, Ordovician period, which began 500 million years ago and lasted for 70 million years, corals and the first backboned animals begin to appear. This was followed by the Silurian period, lasting for 30 million years, when the first evidence of vegetation on land appears. In the next, Devonian period, wingless insects first appear. This was followed by the Carboniferous period (275 million years ago) and the Permian period, when animals started venturing out of the sea, and the first amphibians evolved (350 million years ago). All the above periods together constitute the Primary or Paleozoic era.

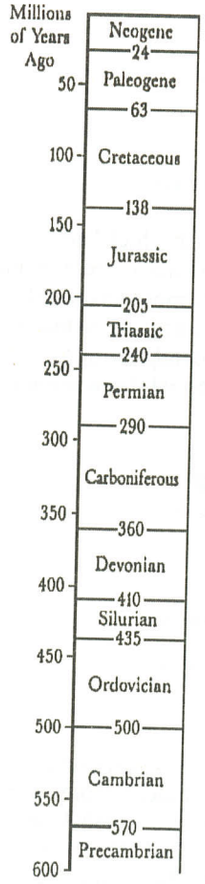


Fig.235 **Geological periods of the earth**

The next, Secondary or Mesozoic era, lasting for 150 million years, includes the Triassic, Jurassic and Cretaceous periods. The end of the Paleozoic era was marked by mass extinction of marine invertebrates, but did not affect land plants and animals. Ferns and conifers now gave way to flowering plants and reptiles, including the giant dinosaurs, flourished.

The last, or Cenozoic era started about 65 million years ago, and comprises the Eocene, Oligocene, Miocene and Pliocene periods (totally called Tertiary). Mammals, which had originated 180 million years ago, dominated the fauna, and the land-masses as we know them today were formed.

Why do some animals survive for long periods of time, while others die out after a few million years? The cause for extinction is rarely single. Usually it is a combination of factors that overwhelm a species. There may be a specialisation of habit and habitat, an absence of adaptability to changing environment, a low rate of multiplication, a diminution of the food supply, and the appearance of a new predator.

Conversely, a living fossil or relict has survived because it has enjoyed a sufficient supply of food, freedom from overwhelming enemies or competition, and has not had to meet catastrophic changes of climate or geography. If it had the misfortune to face the last factors, it has been able to escape to an isolated or inconspicuous haven, or to make good its losses because of its internal vitality and regain its former abundance and range.

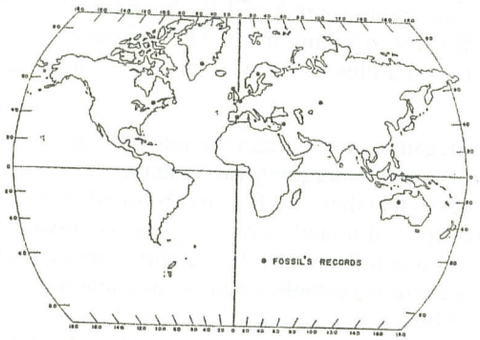


Fig.236 **Where horseshoe crabs once lived on earth (from fossil records). (After Anil Chatterji)**

Once upon a time, horseshoe crabs were found in Europe also. Horseshoe crabs still occur today, but none of them are found in Europe. Some 60 million years ago, they started migrating to east and west. The horseshoe crab is aptly named, for it has a horseshoe-shaped body ending in a spiked tail. The front portion of the body is made

up by the fusion of the head and thorax (chest), and is called the prosoma. On its upper side are a pair of large compound eyes and there is a pair of smaller, simple eyes set close together farther forward. On the lower surface are five pairs of clawed walking legs. The last pair of legs end in leaf-like processes which are used to push away sand or mud when the animal burrows.

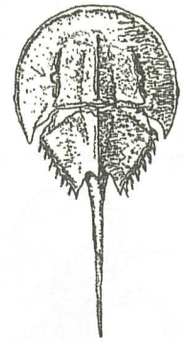


Fig.237 **A horseshoe crab seen from above**

A flexible hinge separates the prosoma from the opisthosoma, which has six pairs of appendages. The first pair are opercula (flaps) covering the genital openings, while the remaining five pairs are its breathing and swimming organs. These have the appearance of thin leaves like the pages of a book, and are called "book gills". A hinged joint separates the spike-like tail (telson) from the abdomen. In the young (called larvae), the spike-like telson is much shorter, looking like a stump. The larvae have a marked resemblance to fossil horseshoe crabs.

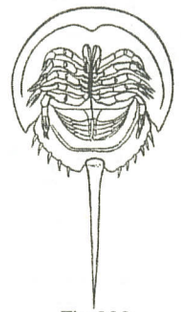


Fig.238
A horseshoe crab seen from the lower side, showing book- gills

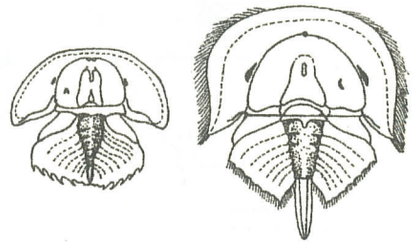


Fig.239
Larval stages of present day horseshoe crabs Note the marked resemblance to fossil horseshoe crabs

The name "horseshoe crab" is a misnomer, for it is not a crab, but is related to spiders. Though we associate spiders with land, there are a few marine spiders also. They are called sea spiders or, sometimes, no-body crabs, as their body is extremely small. Some zoologists place it in the Arachnida, the Class which includes spiders and scorpions. Others contend that it has sufficient structural differences to place it in a separate group of its own, called Xiphosura.

The first written record of a horseshoe crab is in a book *Historia Animalium* written by Joannes Jonstonius in 1558, where it is pictured under the name *Cancer mollucensis* (meaning "the crab from the Moluccas"). Five species of horseshoe crabs occur today– four of them in the Indo-Pacific region. *Tachypleus hoeveni* is found in the Moluccas and *Tachypleus tridentatus* from Indonesia to southern Japan.

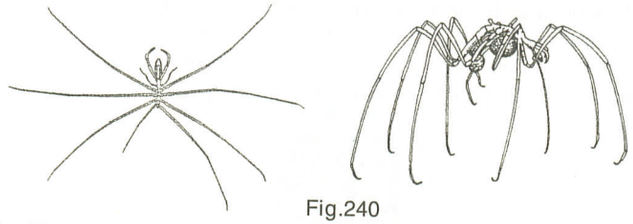


Fig.240

A sea spider (*Nymphon*), top view .It is also called "No-body" crab because its body is so tiny in comparison with its long legs (left) ; male no-body crab carrying eggs on its legs (right). (From Thompson)

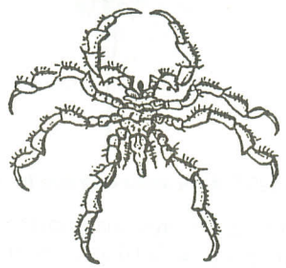


Fig.241 **Another, sturdier, sea-spider (*Pycnogonum*)**

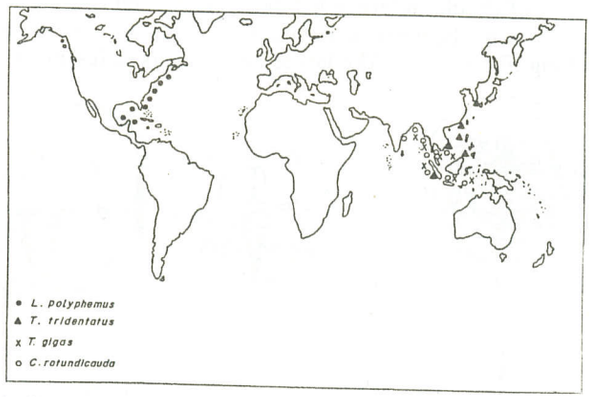


Fig.242 **Distribution of present-day horseshoe crabs in the world. (After Sekiguchi and Nakamura)**

Of the two Indian species, *Carcinoscopius rotundicauda*, growing to 30 centimetres long (including the tail), is an estuarine form, being found in the Sunderbans and also in fresh water with hardly any detectable salt content 60 kilometres upstream from the sea in the Hooghly river from Digha to Canning (near Calcutta), and extending from the western shores of the Bay of Bengal (Hukitola in Orissa) to China. The other species *Tachypleus gigas* (earlier known as *Limulus moluccanus*) is marine, being found from the tide-line down to 15 metres on sandy or muddy bottoms, and extending from Gopalpur in Orissa and West Bengal to Indonesia, Malaysia, Indo-China, North Vietnam and the Philippines. It grows to 45 centimetres. Distinguishing features of present-day horseshoe crabs are given below.

One species, *Limulus polyphemus* growing to 60 cm, is found on the eastern coast of North America in the Gulf of Mexico from Maine (U.S.A.) to Yucatan (Mexico). Here it is also called "king crab", but this should not be confused with *Paralithodes* of Alaska, which is also called "king crab" but, like the horseshoe crab, is not a true crab, being related to hermit crabs.

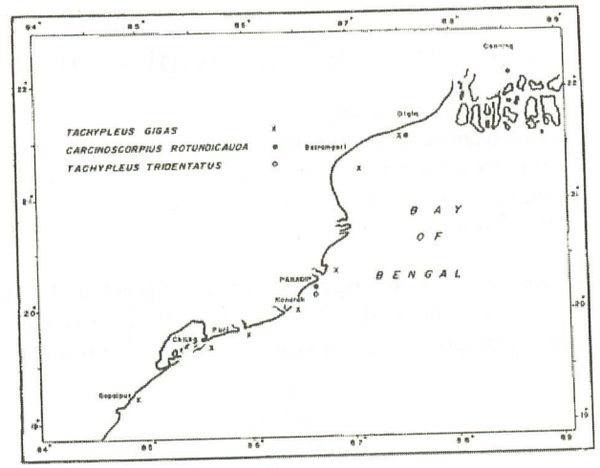


Fig.243

Distribution of horseshoe crabs in the western Bay of Bangal.(There are no horseshoe crabs in the Arabian Sea).(After Anil Chatterji)

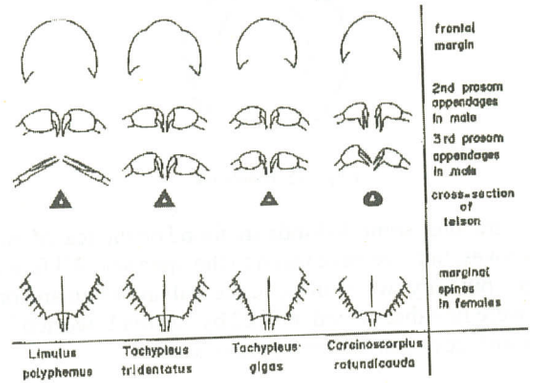


Fig.244 **Distinguishing features of horseshoe crabs (After Sekiguchi and Nakamura)**

During the breeding season, pairs of horseshoe crabs can be seen, sometimes in large numbers, in shallow seas along the beaches. One, sometimes more, of the smaller males grip the larger female and hold tight to it.

30 The bug that walks on water

E'er the wily Halobates
Sees our spray, and skates away.....
The more we tow, the more we get.
Tow them swiftly o'er the foam
And fill our neuston net.

Many of us have seen insects tiptoeing on the surface of ponds and wondered why they do not sink. These are called pond-skaters. We find their relatives on the sea surface, and they are called, very appropriately– "sea-skaters" – scientific name *Halobates*.

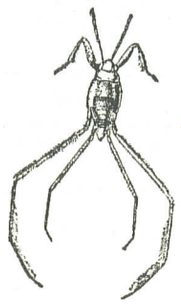


Fig.245 **Halobates**

About half a centimetre long, some 44 kinds are found on the sea. Most of them live near the coast and mangroves, but five have taken to the open sea. All five species are found in the Pacific Ocean, but only two of these in the Indian Ocean and one in the Atlantic Ocean. *Halobates* were first discovered in 1822 by Johann Friedrich Eschscholtz. They can walk on the sea surface as fast as a metre in one second.

Their ability to skate on the sea surface is due to numerous hairs on their legs. These are water-repellent and help to spread the bug's weight over a large area of the sea surface. It is the surface tension on the air-sea interface that enables them to walk. If, however, the water is polluted by, say, detergents, they will sink.

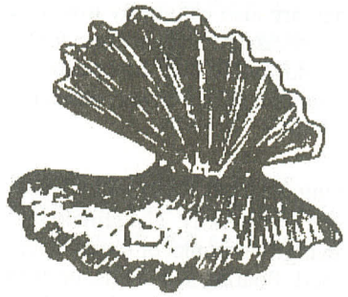
One may wonder how they can spend their entire life on the ocean, withstanding the hot sun, rain and braving storms and heavy seas. Their cuticle (skin) can keep out 99% of ultraviolet rays of the sun. And tiny, 1.5 microns long, hook-like hairs covering their velvety body trap air, giving them buoyancy and enabling them to breathe under water. Just as a cork pushed down below water and then released pops up to the water surface, the insect can bob up after a momentary dunking in the water, They can even live up to 16 hours under water; the oxygen in the air trapped by the hairs is used for breathing. As it gets depleted, air from the surrounding sea water diffuses in. This has been proved in experiments where the insects are kept under sea water boiled to remove dissolved oxygen and then cooled; they suffocate and die in 20 minutes.

Halobates feed on zooplankton at the air-sea interface, fish eggs and larvae. The prey is held by the short front legs and sucked dry. In turn, they are the prey of the floating purple snail *Janthina*. (This snail secretes a raft of slimy air bubbles to which it adheres; the bubbles help it to float.)

The insects are collected by keeping a lamp just above the sea surface alongside a ship. They are attracted by the light and can be caught. They are also caught by towing a catamaran-or manta-plankton net. This is a fine meshed conical net fixed on a horizontal pole between two floating boat-shaped pontoons. It is held so that half the opening is above water and half below it. This net is also used to study oil pollution and skims the sea surface.

The insect probably has a pheromone– a substance giving out a particular smell which can be detected far away– to attract its mate from about a metre away. The female lays 25 to 30 eggs. Near-shore *Halobates* fix their eggs to mangrove trunks or rocks; open-ocean forms search out any floating objects such as wood, floating sea-shells, or even feathers and tar balls for this purpose. The eggs hatch in a month's time to 1 mm-long nymphs.

31 Double-shelled Snails



Mary, Mary, quite contrary,
How does your garden grow?
With cockle-shells and silver bells
And pretty maids all in a row.

A nursery rhyme

Of the various animals on the seashore, sea shells are undoubtedly the most popular. These shells are but the outer covering of an assortment of dissimilar animals collectively but wrongly called "shellfish". They have no backbone and are *not* fish. Scientists call them Mollusca. They comprise animals that are so small as to be almost microscopic, giants with an overall length of 1·8 metres; forms that do not, or hardly, move, and others which swim at great speed.

All molluscs have a soft, unsegmented body, sheathed in a skin called the mantle. Many are enclosed in hard limy shells, formed by glands in the mantle extracting and secreting calcium carbonate from sea water. There are four main groups: the Scaphopoda (meaning "boat-foot"), Pelecypoda (axe-foot), Gastropoda (stomach-foot) and Cephalopoda (head-foot).

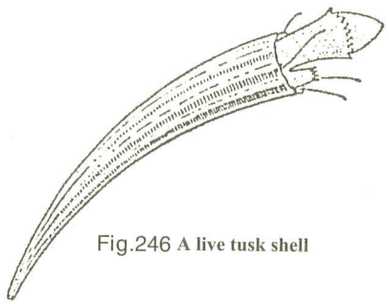


Fig.246 **A live tusk shell**

Tusk shells or tooth shells (*Dentalium*) live in fairly deep water where they burrow in sand, but are sometimes found washed up on the seashore. Belonging to the Scaphopoda, there is no head, eyes, tentacles or heart. The shell is a slightly curved tube, like an elephant's tusk open at both ends and wider at one end than the other. The foot is long and pointed like a boat's prow (hence the name Scaphopoda). Most are less than 25 mm long, and most have a simple, round opening at the narrow (apical) end. However, those belonging to the subgenus *Fissidentalium* have a slit at the apical end.

It lives buried in sand and feeds on Foraminifera and minute bivalves which are seized by bunches of filaments on either side of the mouth A horny, toothed tongue or radula rasps the food like a carpenter's file.

Animals of the order Pelecypoda, popularly known as bivalves, have their soft body protected between two, usually similar, valves of the shell, connected by an elastic ligament forming a hinge. The body is surrounded on both sides by the mantle, which secretes the shell valves. Two large muscles, by contracting, can bring the valves together so as to close the shell when danger threatens. Bivalves have no head, jaws or tongue, and feed on minute particles of food which are sucked in by a current. There are four leaf-like gills– two on each side of the body; these serve the double purpose of respiration and food gathering. Some bivalves have a brownish or blackish covering, called periostracum, over the shell.

The shell is made up of calcium carbonate crystals held together by an organic matrix– a scleroprotein secreted by specialised regions of the animals' mantle. The organic matrix not only glues one crystal to another but, by selectively concentrating calcium in particular regions, actually induces the formation of these crystals.

The mantle is attached at the hinge, but hangs down as two sheets to enclose a chamber, called mantle-cavity, containing the gills. The borders of the mantle may be free or joined together to form a cavity, with openings for entry and discharge of water and for the foot. The mantle edges are often shaped into tubes, called siphons for the circulation of water. Sometimes the two siphons are fused into a single tube with two openings. Cilia inside these create the water current bathing the gills.

The cells of the mantle which produce lime are found all over the mantle but are more on the mantle edge. Growth of the shell, by producing more layers, takes place only here, and so does the laying down of colour in the shell, produced by pigment cells on the mantle edge. The cells over other parts of the mantle lack pigment cells and are used only to repair cracks in the shell or thicken it from inside. These repaired portions consequently lack colour.

Clams come in many varieties, all burying in sand or mud, but they prefer specific salinity (saltiness of water) and size of the mud or sand grains, and are to be found only where these conditions are met. Thus the wedge clam (*Donax*) is purely marine, never entering estuaries, while the backwater clam (*Meretrix*) prefers the low salinities of estuaries.

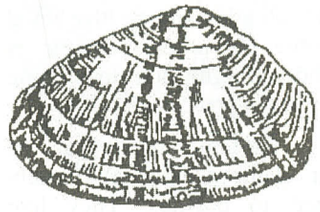


Fig.247 **Wedge Clam**

Wedge clams (*Donax*) are so named because the hind end is abruptly flat. Growing to 4 cm, they are found in thousands just below the sand between tide marks. Two tiny holes in the sand give away their presence. When uncovered by a wave, they extend their foot, turn up on one end and quickly bury themselves.

Like most bivalves, wedge clams cannot "walk" or even crawl. Yet they are able to carry out a unique "migration" up and down the beach. When a wedge clam feels the vibration of an incoming wave, it crawls vertically up from the sand where it has been lying buried. The oncoming wave carries the animal forward. At the farthermost point of transport as the water recedes, the clam quickly buries itself so as to avoid being carried back with the backwash.

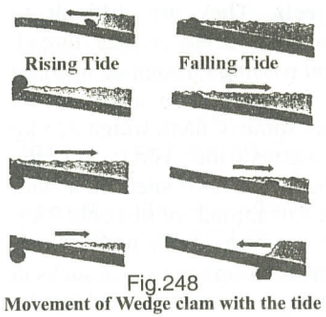


Fig.248
Movement of Wedge clam with the tide

This is repeated at each incoming wave so that, at the end of high tide, the clam is only slightly seaward of the water's edge. On the receding tide, as the animal feels the downward (seaward) current of water, it emerges from the sand and is carried down the beach by the backwash. As the next wave surges up, it quickly buries itself, to emerge again at the next backwash. Thus, at the completion of ebb tide, it lies just higher (landward) than the water's edge.

Several methods are used to determine the age of bivalves. In some clams, annual growth layers can be seen in the chondrophore– the tooth that holds the two valves of the shell together. These layers can be read in the same way as the rings of a tree trunk. Cross-sections of the chondrophore are cut, and the cut surfaces are chemically and physically treated to show the internal layers that are deposited yearly. Annual growth layers can also be viewed when light is transmitted through thin cross-sections.

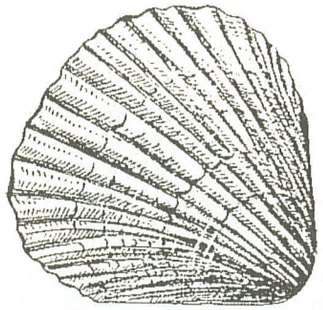


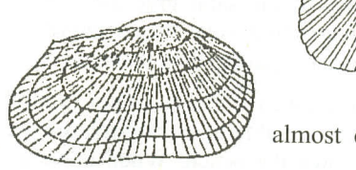
Fig.249 **Cockle**

Most bivalves live buried, and do not require to move fast or see. But cockles (*Cardium*) do hop about. Their convex, deep-bodied valves, when seen from the side, look like a heart, and hence their scientific name. The valves are adorned with over two dozen raised ribs. The pointed foot can be bent in the middle (like our elbows) so as to double on itself and then straighten like a spring. This movement, when repeated, results in a series of hops.

The false cockle (*Cardita*) also has two heart-shaped, deeply ribbed valves with radiating ridges. Found on sandy or gravelly bottom, they too can hop about using the sickle-shaped foot. A common and pretty species is *Cardita bicolor*, having rows of red spots on a white shell.

Fig.250
Some ark shells

Ark-shells, superficially resembling cockles, can be distinguished by the hinge having a straight row of many tiny teeth. Its blood is red (unlike the colourless or pale blue blood of other bivalves), and it is considered highly nutritious, being given to pregnant women.



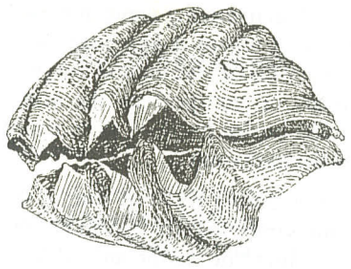


Fig.251 **Giant clam**

The largest bivalves are the giant clams (*Tridacna*), closely related to cockles. They live almost completely buried among dead coral rock in the lagoons of coral reefs. They are difficult to extricate, as they attach by a strong "byssus" thread, made by the clam and passing through an opening at the upper portion of the shell. Growing at the rate of 8 to 12 cm per year, some of them weigh 225 kg and have a shell 1·4 metres wide. But most of the weight of giant clams is due to its shell. In a clam weighing 225 kg, the soft animal weighs only 9 kg. Two tubes jut slightly out from the shells. Of these, the larger one is the inhalant siphon (which sucks in sea water for breathing and feeding), while the smaller exhalant siphon expels the water. In bright sunlight, their deeply fluted shells gape so as to expose the beautifully coloured violet or dark green mantle fringe. Tiny one-celled algae called zooxanthellae live inside the tissues of the giant clams, and it is to expose these to sunlight that the animal gapes. A 90 kg giant clam releases one billion eggs per spawning. Almost 80% of the clam's food is manufactured by the zooxanthellae.

Almost all books on seashells speak of the fate of native divers whose foot or hand has been caught between the valves so that he suffocates and drowns. Although the adductor muscle (which shuts the shell) is very massive and powerful, the valves do not

close with a snap but rather slowly, so that it would be someone with very slow reflexes to allow his limb to be thus trapped. Moreover, adult clams lose the ability to shut the shell valves completely. The belief that its muscles are so powerful that if a man inserted his hand between the valves, he would have to leave it in the tremendous grip until its death, started with Darwin. They do not like to dry up and are found below the low-tide mark.

There are five living species of *Tridacna*, viz. *T. crocea, T. derasa, T. gigas, T. maxima* and *T. squamosa*.

They change their sex during growth, being born as males, and becoming female at six years. When mature, they spawn (shed milt or eggs) in the late afternoon during early or mid-summer. Sperms are shed first, followed by eggs. It is believed that some chemicals are released into the water which induce their neighbours to spawn. The eggs hatch in 16 hours to larvae which drift in the plankton for a week, and then settle to the sea bottom. In another three days, they become juvenile clams, but they can move around with the help of their foot for some time.

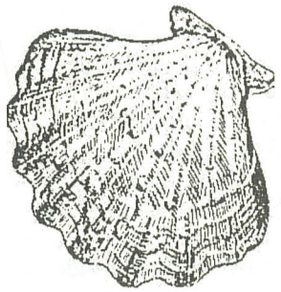


Fig.252 **Scallop**

Scallops (*Chlamys*) are distinguished by the presence on either side of the hinge, of a flap called auricle or "ear". The stout shell is further strengthened by many broad ribs to give a corrugated appearance. The mantle edge is beautifully fringed to produce many "tentacles". It also has pigmented spots, called ocelli which serve as primitive eyes to detect any movement nearby. These ocelli look like a double row of shining bluish green beads, each of which occupies the middle fold of one of the scallop's mantle margins. There the eyes share space with many sensory tentacles. There may be up to 100 eyes. Each tiny (1 mm diameter) eye has a cornea, lens and a double-layered retina. The light-reflecting layer behind the double retina gives the metallic blue-green sheen to the eye. It increases the sensitivity of the eye by reflecting light back through the two retinal layers.

The eyes can distinguish boundaries between light and shade, but cannot form sharp images. Basically, they are used to detect approaching predators. The scallop can hop about by flapping its shell valves open and shut, and does this when it perceives a sea-star or crab creeping up on it. *Pecten jacobus*, or St. James' shell was used as a badge by Christian pilgrims to the Holy Land.

Who quit his cell, his pilgrim staff he bore,
And fixed the Scallop in his hat before.

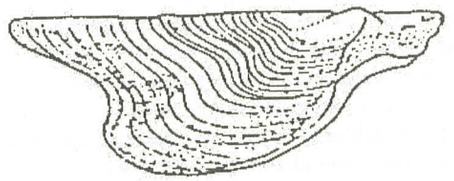


Fig.253 **Wing shell**

Prominent ears are also present in pearl oysters and wing shells (*Avicula, Pteria*). In the latter, the hind ear is elongated into a long spine looking like a swallow's wing. The young live among sea fans or hydroid colonies, and they are admirably camouflaged. The inside of the shell has partly a mother-of-pearl lining.

Hammer oysters (*Malleus*) are named from the black wrinkled T-shaped body.

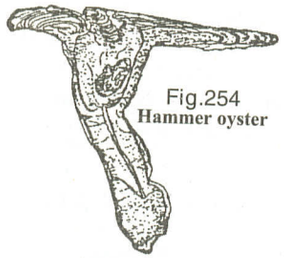


Fig.254
Hammer oyster

The two "ears" form the top of the 'T', the body being the vertical stroke of the 'T'. The shells are overgrown with sponges, hydroids, sea-mats and sea squirts.

Thorny oysters (*Spondylus*), also called thorny cockles, are related to scallops, having the latter's eyes bordering the mantle. The shell valves are covered all over with long, blunt spines. They are brightly coloured red, purple or yellow and live attached, like oysters, on rocks and corals. Unlike the clams which dig into mud or sand, oysters settle on rocks or other solid substrate. The left shell valve is fixed to the rock and, as in scallops, there is only one adductor muscle (to close the valves).

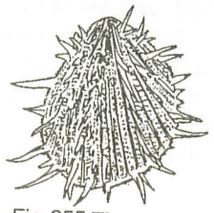


Fig.255 **Thorny oyster**

The man had surely a palate covered o'er
With brass or steel, that on the rocky shore
First broke the cozy oyster's pearly coat,
And risked the living morsel down his throat.

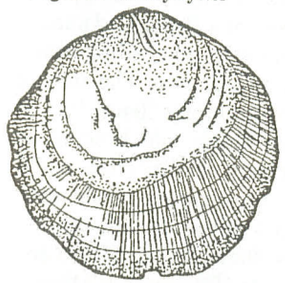


Fig.256 **Window-pane oyster**

The window-pane oyster (*Placuna placenta*) has very flat translucent shell valves, some 15 cm in diameter, looking like mica. In the 16th century, when glass was expensive, its shell was used for glazing windows and verandah roofs. The Chinese cut 5 cm squares from its shell and fixed these between wooden strips to serve as window panes. The Portuguese borrowed the idea and introduced it in Goa and Diu in the 16th century. Many old villas there and the Governor's Palace at Mourmogao have these windows.

The Archiepiscopal Palace in Velha (Old) Goa, built in 1560 as the seat of the Archbishop of Goa and Patriarch of the East Indies, also has oyster-paned windows.

Calcined (burnt) pearls from windowpane oysters are used by wealthy Indians as chunam (line) with betel and paan leaves. The burnt pearls are also used as 'kohl' or 'surma' (mascara or eye liner) for children. In Indian medicine, they are boiled with certain leaves and flowers, reduced to a powder with burnt coral, and used to treat tuberculosis. Earlier, the pearls were placed in dead rich people's mouth at cremation.

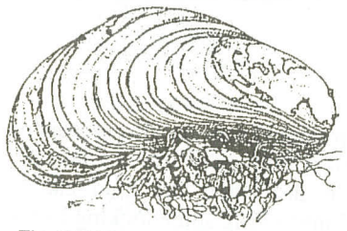


Fig.257 **Mussel with byssus threads**

Other bivalves that do not bury in the sea bottom are the mussels (*Perna*– formerly *Mytilus*). Their dark green or brown elongated shells grow together in clusters, sometimes of hundreds of shells. Their foot has a gland which secretes a fluid that hardens to a thin but strong thread, called byssus, when it comes in contact with sea water. With these byssus threads or "beards", mussels cling to rocks, wharf piles and buoys. This attachment is not permanent; when a mussel wishes to shift, it can discard its byssus and grow new ones. Mussels have been used for a quaint purpose by engineers. Because of their strong and tenacious anchorage, live mussels are often used to repair bridges, by filling the interstrices of bridges where the tidal currents are so strong that mortar and cement cannot be poured in.

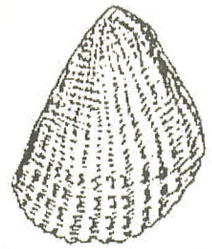


Fig.258 **File Shell**

Yet another bivalve which spins byssus threads is the file shell (*Lima*), so called because its shell has rough file-like ribs. It collects pebbles, shell fragments and debris and weaves these among byssus threads to make a nest. Many young make a community nest, but the adult prefers to live alone in its own nest, albeit in the company of a scale worm (*Polynoe*) and a porcelain crab. When disturbed, *Lima* hops about like a scallop by opening and closing its valves several times.

The byssus-thread bundles which anchor the bivalves to hard objects are extremely resistant to harsh conditions. This resistance results from a process called quinone-tanning. A scleroprotein exuded by one gland is tanned by another substance produced by another gland.

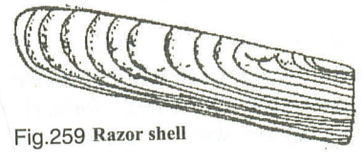


Fig.259 **Razor shell**

The razor-shell (*Solen*) has a long, narrow body between two polished rectangular valves, up to 15 cm long, and looking like the barber's old-fashioned cut-throat razor. On a sandy seashore you will often be intrigued by a jet of water shot out from the sand. It is caused by this animal. It is a swift and powerful burrower. To start burrowing, the razor-shell lengthens its pointed foot, driving it a few centimetres into the sand. Now its tip suddenly swells into a knob, so that it becomes tightly wedged just below the entrance of the burrow. By a series of such thrusts and swellings, an inclined and then vertical burrow is made, until the animal disappears from view, the only indication of its whereabouts being a keyhole-shaped narrow opening on the surface. Although the razor shell lives in salt water, it has a strange aversion to salt. A pinch of salt poured over its burrow will bring the razor shell popping up to the surface. It is often caught this way. But once it is taken up and put down in the mud and allowed to burrow, no amount of salt will make it pop up again.

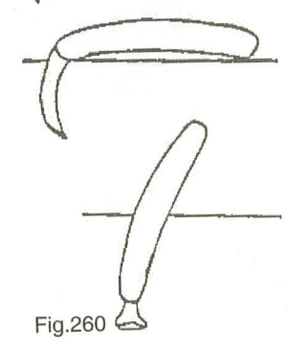


Fig.260
Burrowing action of razor shell

Just as molluscs have different methods of locomotion, such as crawling, hopping, digging and burrowing, so too have humans– walking, cycles, cars, scooters and rail trains. When the flyover near our Aquarium came up, it was closed to pedestrians. One day I was cycling on it when a policeman stopped me and asked me to dismount. When I asked him why, he pointed to a board picturing a man walking, a handcart, a bullock cart and a horse buggy (locally called a victoria). There was a prominent cross against them, and a sign reading "Closed for pedestrians and animal drawn vehicles". For my bicycle to be depicted as an animal-drawn vehicle was probably the worst humiliation in my life! Anyway I dismounted from my bicycle and started walking. The cop stopped me again, this time saying that since I was walking, I had become a pedestrian, which category was also banned. When I asked him whether I should use the flyover by turning somersaults over it, he told me not to be funny but to go back and take another road instead of the flyover.

Fig.261 **Watering-pot shell**

Distantly related to the shipworm (*Teredo*), which is not a worm but a bivalve mollusc burrowing in wood are the watering-pot shells (*Brechites*, formerly *Aspergillum*). Burying upright in the sand just below spring low-water mark, the 7 cm long shell is a brittle limy tube with the bottom closed but perforated by many holes, resembling the rose of a gardener's watering-can. On the periphery, surroundings these holes, are short, open-ended tubes. Near the upper end are a few frills encircling the shell, which is open at the top end. That this odd-looking shell is a bivalve can be made out by the presence of a tiny bivalve shell buried in the tube just above the lower end. The main tube is secreted by the animal's siphons.

32 Drillers in the Sea

O That this too too solid flesh would melt,
Thaw, and resolve itself into a dew.

Shakespeare, In *HAMLET*

Wood still forms an important material for construction of small boats as well as harbour and jetty pilings, because of its low cost, ready availability, resilience and ease of shaping. But, like almost all organic materials, it is subject to attack by diverse marine creatures. One of the most destructive agents is the shipworm. It has been a curse for over two thousand years; the Greek Publius Ovidius (43 B.C.-17 A.D.) noted: "For as the ship by hidden shipworm spoil'd."

Shipworms are not worms, though their appearance suggests so. They are related to clams and oysters. Belonging mainly to the genera *Teredo* and *Bankia*, the adults are soft, about the thickness of a pencil, and may be from 15 cm to over a metre long. That they are molluscs can be seen by the presence of two tiny shell valves at the front end. There are more than 65 kinds of shipworms.

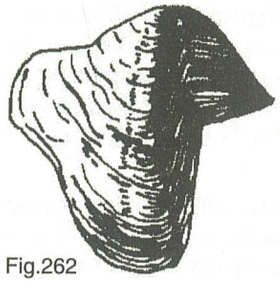


Fig.262
A shell valve of the ship worm

The animal starts its life as a free swimming larva which has to find a piece of wood within, depending on the species, three to thirty days. Once it comes across wood, the pair of hard, oval, rasp-like shells rotate to and fro to make a pin-hole in the wood. Once in, the shipworm turns and burows along the grain of the wood, travelling in a straight line. As the shipworm grows, its cutting shells also increase in size, so that the diameter of the burrow increases. Once the larva has bored into the wood, the shipworm will never leave its burrow.

We are the Little Forkwe!
Too little to love or to hate;
Leave us alone and you'll see
How we can drag down the Great!
We are the worm in the wood!
We are the rot at the root!
Mistletoe killing an oak
Rats gnawing cables in two
Moths making holes in a cloak
How they must love what they do!
Yes, and we Little Folk too,
We are busy as they
Working our works out of view
Watch, and you'll see it some day!

Rudyard Kipling

As it burrows, the shipworm lines the burrow with a limy material resembling an egg-shell. It pumps its soft body full of water, pressing it against the wall of the burrow so as to get enough leverage to rasp further into the wood. If the shipworm comes across an obstruction, such as a nail, a knot or crack in the wood, or another shipworm's burrow, it changes the direction of its own burrow. If the space for burrowing is too narrow, the shell valves stop growing, so that, instead of widening its burrow, the diameter is

just less than the thickness of the wood. If, by chance, lack of space forces it to break the surface of the wood, the shipworm will soon die.

So the forest tall that groweth
Underneath the waters clear,
Does the woodman Mollusk
Level every year;
From small causes, great results
Teach you to persevere.

Fig.263 **A shipworm [*Teredo*]**

At the rear end of the shipworm are two tube-like siphons– one to pump in sea water for breathing, and the other to eject waste matter. If the water quality degrades (lack of oxygen or a chemical poison), the shipworm withdraws its siphons and plugs the entrance of the burrow with two prongs at its "tail", called pallets. It can survive for weeks after sealing itself thus.

For breeding, *Teredo* females suck in sperm through their siphon to fertilise their eggs, and carry the young in a brood pouch. A *Bankia* male thrusts its exhalant siphon into a nearby female's inhalant siphon and pumps his sperms in. After fertilisation, the eggs are ejected into the sea. If the sexes are too far apart, the sperms are released into the sea, while the female also releases her eggs outside. *Bankia* start life as males and then change sex to become females; if the females live long enough, they again revert to become males.

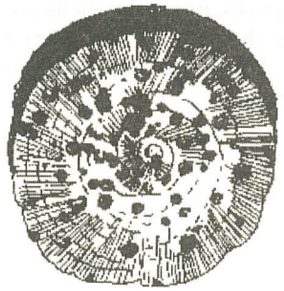


Fig.264
Section through wooden piling showing tunnels of shipworms

Man has been constantly waging a war against the ravages of shipworms. As these stop burrowing in sea water of salinity less than 10 parts per thousand (the normal salinity of sea water is 35 ppt) and then die, boats are anchored for a few days in rivers to get rid of them. Wood in the vicinity of nails is not affected by shipworms, so ancient Greeks and Romans resorted to driving large-headed nails close to each other in the wood. In the 17th century, ships' hulls were sheathed with lead sheets below the waterline. Later, lead was replaced by copper as it not only kept off shipworms, but also prevented fouling of the hull due to settlement of barnacles, sea-mats and hydroids.

An ingenious method, still in use, was "Verhanderung"– stuffing cow's hair between the oak planks of the ship's hull and an outer, cheaper wood such as fir. It was believed that the shipworm got entangled in the hair. This is not true, but the method worked. The real reason is that the shipworm is unable to burrow in any space between two pieces of wood. Nowadays a layer of felt impregnated with tar is attached to the keel of yachts, and a false keel of cheaper, replaceable wood is attached onto the keel.

Apart from mechanical protection, chemical preservatives are also used. The commonest is creosote– a by-product during coke production. It is injected into wood by steam heat and pressure so as to saturate the outer sapwood portion. It is effective for five to ten years. Creosote-treated wood is also resistant to insects, fungi and bacteria.

Shipworms can sense the presence of poisons in the water and close their burrows with their pallets. To kill them, there should be a chemical which they cannot sense. One such is sodium arsenite, now used for protecting the pontoons of floating wooden dry decks.

Every hated animal has its admirers; natives of Fiji Islands and Thailand consider shipworms a delicacy and extract them from their burrows.

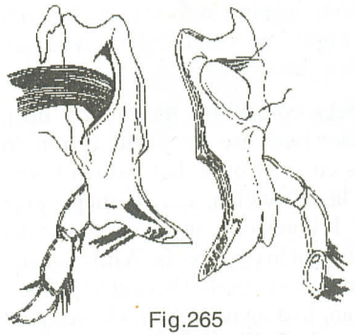


Fig.265
Jaws of a gribble showing "rasp & file" combination [After Hoek]

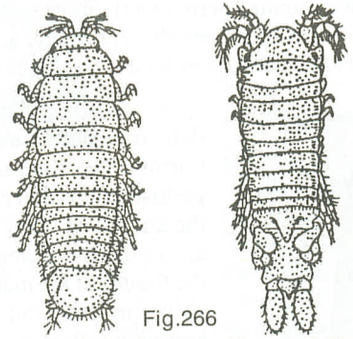


Fig.266
Two kinds of gribble: *Limnoria* [left] & *Chelura* [right] [After Calman]

Non-mollusc wood-destroyers are the isopod crustaceans known as gribbles (*Limnoria*). About the size of a rice grain, they use their jaws to chew wood. They make shallow tunnels just below the surface of the wood. Thus weakened, the surface breaks off, and the next layer of wood is now attacked. As only wood between low-tide and half-tide level is attacked, an hour-glass shaped remnant of piling results, above and below which the wood is not at all damaged.

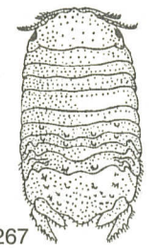


Fig.267
Putty bug [*Sphaeroma*] [After Calman]

Less destructive are the isopods known as putty bugs (*Sphaeroma*), which chew away caulking in the seams of boats. Related to *Limnoria*, they seem to have a definite preference for the material used for caulking the seams of wooden boats. Their burrow holes are about 3 mm in diameter.

The very deep did rot: O Christ!
That ever this should be!
Yes, slimy things did crawl with legs
Upon the slimy sea.

Coleridge

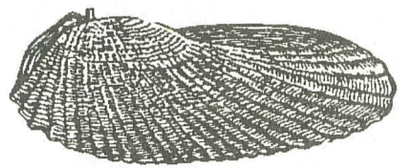


Fig.268 **Piddock or angel's wing shell**

Piddocks or angel's wing shells (*Pholas*) have a thin, long, white, fragile shell with accessory plates on the upper surface, with rows of sharp pointed spines along the anterior (front) surface of each valve. Some grow 12 cm long, while others may be only a cm in length. The shell valves do not enclose the body so that the long cream-coloured siphons and the strong transparent foot remain outside. Piddocks are efficient borers, drilling into dense clay, soft mudstone and shale, or harder sandstones and limestones, but never into the hardest rocks such as granite. Some also bore into wood, but they are not common on coral reefs. The rounded foot is used as a sucker to hold the animal against the burrow. It rotates, first in one direction and then the other, and its tip, studded with sharp flint crystals, grinds away the rock.

The worn-out crystals are replaced by a new set. The file-like teeth on the shell are used to increase the diameter of the burrow as the animal grows. While boring, jets of water from the siphon blow away the powdered rock particles. The movement of the shell valves is different from other bivalves. In others, the adductor muscles which close the shell, both contract together to close the shell. In piddocks, the muscles contract alternately, so that the front and rear ends in turn come together and then separate.

The piddock remains permanently in its burrow, sucking in food particles with its siphon. It is bioluminescent and shines brightly at night with a bluish glow. What use this is to an animal which always hides in a burrow is not clear.

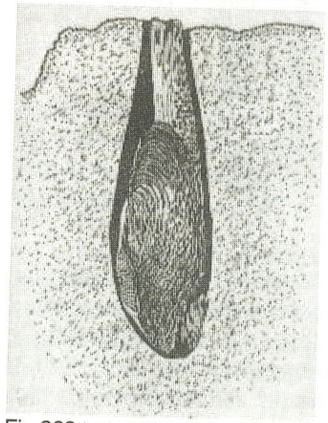


Fig.269 **A piddock in its rock burrow**

While piddocks bore like a mechanical drill, date mussels (*Lithophaga*) use chemical action to burrow. The shell is covered by a dark brown horny periostracum (outer layer), which, and the shape, give the animal its name. It bores only in calcareous rocks and is, therefore, abundant in coral reefs. While boring, the tissues of the mantle are extruded between the shell valves in front and applied against the rock. An acid secretion softens the rock, and the soft paste is removed so that the animal moves deeper into the rock. A few byssus threads hold the animal in position.

Smaller cousins of the giant clam (Tridacna) also burrow in dead coral rock, where they are extremely abundant. They grow only to 10-12 cm and have a deep, broad body.

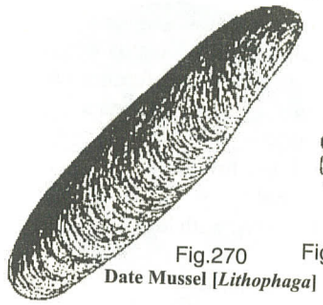


Fig.270 **Date Mussel [*Lithophaga*]**

Fig.271 **Calcarous rock showing grooves made by date mussels**

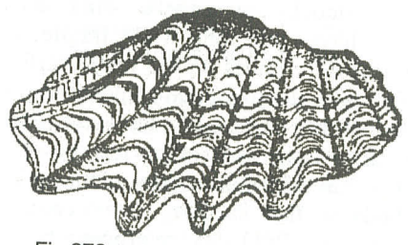
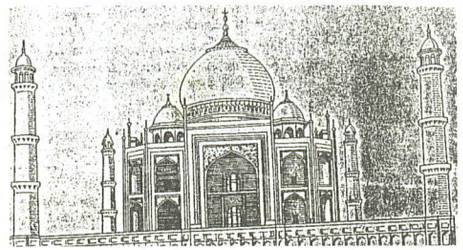


Fig.272 **A giant clam [*Tridacna*]**

33 Taj Mahals in the Sea



Can all that optics teach, unfold
Thy form to please me so,
As when I dreamed of gems and gold
Hid in thy radiant brow.
When Science trod Creation's Face
Enchantment's veil withdraws,
What lovely visions yield their piece
To cold physical laws!

Together with precious stones such as diamonds, rubies and emeralds, one of the most prized favourites is the pearl. Worn today by ladies, it was once the favourite of maharajahs and princes, whose portraits depict pearls adorning their turbans as well as ear lobes. The fashion goes back to the Roman Empire, when pearl earrings were so heavy and massive that the ears were misshapen into infected cauliflower-like tumours. Seneca wrote tongue-in-cheek, "The ear lobes of our ladies have attained a special capacity for supporting a great number of pearls and possibly doctors."

Apart from use as gems, pearls also play a role in medicine; the ashes of burnt pearls form a basic ingredient of many Ayurvedic potions. And Mikimoto, the Pearl king of Japan (of whom we shall see later) attributed his vigour at the age of 94 to his habit of eating two pearls every day. They also play a cultural role in the beliefs of people around the world. On the island of Margarite– the centre of the pearl fishery in the Atlantic Ocean only married women wear Peoria. They are said to bring tears to the eyes if worn by single girls.

How pearls are formed was for long a mystery. Ancient Greeks surmised that pearls were formed when lightning struck the sea. Others thought that oysters came up to the sea surface, opened their shell, and an angel's tear fell into them to crystallise and form a pearl. Columbus saw oysters clinging to the roots of mangroves and thought that dew drops from the mangroves fell into the oysters' open shells and formed pearls. Some thought that pearls were gallstones formed in oysters when they fell ill; others thought that "surplus shell fluid" from the oyster's ruptured internal organs hardened to form pearls. Hume, in 1825, said that the oyster's undischarged eggs formed the pearl's centre.

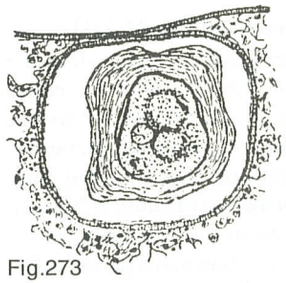


Fig.273 **Pearl forming around 3 sand grains inside an oyster's body**

It was Redi who, in 1671 was on the right track when he claimed that sand grains found in the pearl's centre produced them. Later, Von Boar found the egg of a parasite inside a pearl and claimed that the pearl's nucleus was foreign organic matter. Now we know that both of them were right. A pearl is formed when foreign matter enters an oyster's body while the shell is open and irritates the animal. The oyster tries to expel the particle; only when it cannot does it change its strategy. The oyster has no hands to pluck it off, so its solution is to secrete nacre (mother-of-pearl, the iridescent substance lining the inside of the shell valves) by the cells of the mantle (a membrane covering the animal's body). Layer after layer is secreted around the irritating substance, ultimately forming the pearl. The cause is usually a sand grain, a tiny bit of broken shell or a pea crab, but, especially in oysters from Sri Lanka, it is the larva (baby) of a Cestode (tapeworm) parasite. Our society ladies would be aghast to know that the string of pearls they are wearing could be the (albeit glamorous) tombs of worms! Of course it is a matter of speculation as to which is more fascinating to behold: the Taj Mahal of Agra, or the pearl

which is as exquisite a sight for thousands of years. Most oysters produce only one to three pearls, but Chinese fishermen off Kwantung province in 1958 found a staggering 1,716 pearls in an oyster.

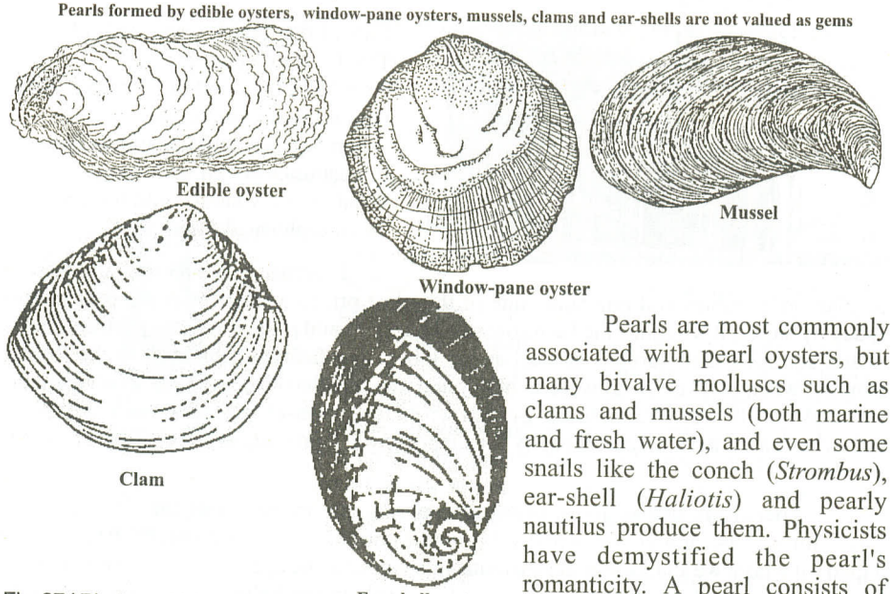


Fig.274 **Bivalves which produce pearls**

Pearls are most commonly associated with pearl oysters, but many bivalve molluscs such as clams and mussels (both marine and fresh water), and even some snails like the conch (*Strombus*), ear-shell (*Haliotis*) and pearly nautilus produce them. Physicists have demystified the pearl's romanticity. A pearl consists of concentric layers of a form of calcium carbonate called aragonite. These layers are cemented together by an organic substance called conchyolin, which is similar to the keratin of our finger nails. In a typical mollusc shell, there are three layers of calcium carbonate deposited on a base of conchyolin. The outer layer looks like porcelain and is formed of vertical crystals of calcite; the chalky shell of an edible oyster is typical. Below this, in most molluscs there is another calcite layer with its crystals laid in a different direction than the first (outermost) calcite layer. However, in some molluscs this layer is formed of another form of calcium carbonate crystals (aragonite). Lastly, there is an innermost calcite layer.

In shells having a nacre (mother-of-pearl) sheen, the two (outer and inner) layers are very thin, and the shell is mainly made of the middle nacreous layer. Here the crystals are in the form of minute thin plates arranged horizontally with the edges overlapping like the tiles of a roof. Light falling on these edges is diffracted and we see the iridescence, similar to the rainbow-like colours of oil spilt on a wet road. In pearls, the nacre is deposited as thin, overlapping hexagonal layers or "leaves", and light striking these undulating leaves gives the same effect. The formation of nacre is faster in warm waters, but slowly deposited nacre is harder, more lustrous and has finer grains. On an average, a pearl consists of 92% aragonite, 6% organic binding material and 2.5% water. Sometimes a calcite layer, instead of aragonite may be deposited on a pearl; this happens in strong sunlight and in acidic water, and decreases the pearl's lustre and colour. Darkness and intense blue light inhibit calcite secretion while stimulating aragonite. Pearls may be pink, silvery, cream, golden, green, blue or black. (Black pearls are actually gray to greenish black.)

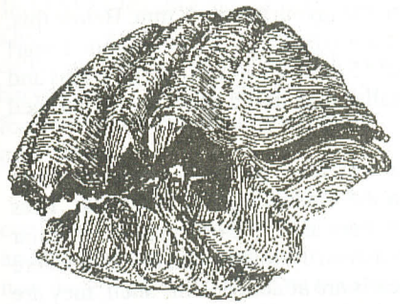


Fig.275 **The giant clam (Tridacna gigas) can produce a pearl weighing over 6 kgs.**

Many a time we read in newspapers that someone dining on oysters in a restaurant had a windfall by finding a pearl on his dinner plate. Such pearls are mainly composed of calcite, have little lustre and are of no commercial value. Edible oysters do not produce nacreous pearls. The largest such pearl was obtained from a giant clam (*Tridacna*) which grows to 225 kg; the pearl weighed 6.3 kg. Compare this with the largest known real pearlthe Pearl of Asia, weighing 2,500 grains (= 162 grams; pearls are weighed in grains). The second largest, the Hope Pearl is 1,860 grains (120 g).

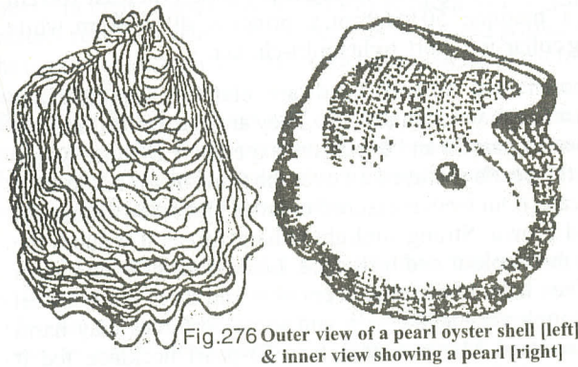


Fig.276 **Outer view of a pearl oyster shell [left] & inner view showing a pearl [right]**

The pearls of commerce are produced by pearl oysters (*Margaritifera*, formerly *Pincttada*). They are more allied to scallops than to edible oysters. Our Indian pearl oyster (*M. vulgaris*) is small, growing upto 9 cm. It occurs sporadically everywhere on Indian coasts, but in abundance in the Gulf of Mannar and Palk Bay in south India, and in the Gulf of Kutch. At Palk Bay the sea bottom is muddy and soft, and the pearl oysters have to settle on the dead valves of other molluscs, but at the other two places commercial gathering is done. In fact, the pearl fishery in the Gulf of Mannar goes back two thousand years. As in the Red Sea and Persian Gulf which too, are renowned for pearl fishery, the pearl oysters are collected by native divers holding a large stone attached to a rope and diving down 25 metres to gather the oysters and bring them up. Their only aid is a bone clip to close their nostrils.

There are two moments in a diver's life;
One, when a beggar, he prepares to plunge;
Then, when a prince, he rises with his pearl.
Browning

The largest pearl-producing oyster is the Silver-lipped Oyster of South Seas. Black pearls come from the Black-lipped pearl oyster (*M. margaritifera)* in the Tuamoto Archipelago; solitary individuals of this oyster are occasionally found on Indian coasts but they are much more numerous in the Persian Gulf. The Gold-lipped Oyster (*M. maxima*) of the Torres Straits (Australia) grows to a whopping 35 cm but is gathered mainly for its mother-of-pearl, though occasionally it yields a pearl. Before the advent of plastics, mother-of-pearl was in great demand for making buttons, brooches, cameos and knife handles. The only pearl fishery in the Atlantic Ocean is in the Caribbean Sea, at and near Margarita and nearby islands. Columbus, in 1498, found that no native woman went without gold earrings and pearl necklaces. Here the pearl oyster is *M. radiata.*

Though some pearls are as large as 18 mm, the favourites are 8 mm. Below this, the price drops drastically. Four pearl grains make a metric carat. A 25-mm round pearl (extremely rare) weighs 450 grains, a 12-mm pearl 55 grains, a 6-mm pearl 7 grains and a 3-mm pearl weighs about one grain. Pearls smaller than half a grain are called seed pearls, and those under 1/25 grain as dust pearls.

As gems, the most prized pearls are those which are perfectly spherical; these are found within the tissues of the mantle or in the connecting visceral mass. Less expensive are the pear- shaped drop pearls. Then there are the misshapen or irregular pearls called baroques. Button pearls are formed between the mantle and the shell where foreign matter entering the shell settles. Blister pearls are attached to the shell; they are mostly formed when a parasitic worm bores into the shell from outside and the oyster isolates it by coating it with nacre. Blisters and buttons are the commonest pearls.

Pearl necklaces are named according to their lengths. A 'rope' is at least 100 cm long, an "opera" is 70 to 80 cm, a "matinee" 50 to 60 cm, a "princess" 40 to 50 cm, while a "choker" is 35 to 40 cm. A 'dog collar' is a short, tight multi-choker.

A pearl's shimmer is known as its "orient". Pearls are relatively soft; they may get easily scratched even against rough woollen clothes. They are also brittle, and can get crushed underfoot, as has been a painful and expensive experience to those whose necklace string got broken and the pearls scattered all over the floor. Their hardness is 2.5 to 4 on the Moh's hardness scale. (Our teeth measure 5 or more.) Exposed to heat and pressure, they will turn dry and brown. Strong sunlight is harmful, as it reduces the pearl's water content, affecting their colour and brilliance. Locked away in an airless drawer, they will deteriorate. They have to be worn every now and then; our body oil helps to retain their lustre, although very acidic skin and some perfumes may harm them. A millionairess who possessed Marie Antoinette's 53-pearl necklace fed it periodically to her pet goose; she believed that its passage through the bird's gut made the pearls shine. Pearls readily burn, and they dissolve in acid but very slowly, as the horn-like conchyolin framework protects them. The story goes that Cleopatra dissolved a large pearl in wine and drank it. If true, she must have either crushed it before putting it in wine, or waited several days until it fully dissolved.

People have, over the ages, always tried to emulate and even improve upon Nature. And man's innate curiosity has helped. He noticed that there was a striking similarity between pearls and the inner lining (mother of pearl) of the shells in which they are found. As early as the 13th century, the Chinese introduced tiny Buddhas made of lead into fresh water mussels, where they got covered with nacre. These pearl Buddhas were used as temple offerings. Notes made by Linnaeus and read after his death indicated that he had cultured pearls in 1748, but he did not describe his methods. In 1884, some people from Tahiti drilled a half-inch hole in an oyster shell. They stuck a glass bead on the tip of a brass rod, pushed it into the hole and plugged the hole with cork. But this failed to produce a pearl. Around this time a marine biologist Takasuhei Mise, a carpenter Tokichi Nishikawa and the son of a noodle seller Kokichi Mikimoto independently but simultaneously discovered that nacre was secreted by the mantle in oysters of Ago Bay (Japan). Mikimoto persisted with his experiments and found out that mother-of-pearl is formed around a "seed" of foreign matter to form a pearl. This was in the late nineteenth century. He employed women divers because women have more fat than men and can withstand longer immersion in the cold water. In a single year he seeded 300,000 oysters with sand, lead, wood or glass and obtained flat pearls.

In 1890, he leased a thousand hectares in Ago Bay, grew one million oysters employing a hundred women, and obtained 30,000 pearls. In 1908, he got a patent for his method of culturing pearls. He expanded his periculture (pearl culture) business until he was harvesting 12 million oysters. It was his venture which gave the lead to Japan as the foremost producer of cultured pearls– some 70 tons a year. Today Japan has over 2,000 pearl farms.

The method employed today is to use 3-year old oysters. Dozens of these are confined in a small area so as to slow down their metabolism. The shell is wedged open and the foot immobilised with a metal clamp. A cut is made in the viscera (body organs) near the gonad. A "seed" or nucleus in the form of a spherical bead cut from the shells of fresh water mussels, together with a small square piece cut from the mantle of another oyster, are inserted into the cut. The oysters are then placed in cages hanging from floating bamboo rafts. At first the oysters were left for three years before harvesting the pearls in them. Later, this period was reduced to 1½ years. Nowadays, in the craze for instant results, oysters are sometimes harvested within six months. But these oysters have not had enough time to form a thick coating of nacre, so that the pearls easily crack and wear down. Sometimes, as many as six nuclei are implanted in a single oyster. Pearls are found in about half of implanted oysters; the other oysters either reject the implants or die. Forty percent of such pearls are of saleable quality, though flawed because of scratches, cracks, chips. bumps or pits, welts and discolouration; only one in eight is perfect enough to be a gem.

Cultured pearls fetch a lower price than natural ones, but they may still be too expensive for some. The cheapest 'pearls' are what are known as "simulated pearls". They are not pearls at all. They are just hollow glass or plastic beads coated inside with 'pearl essence'. Pearl essence is also known as essence d'orient or fish silver. This is obtained by scraping off the scales from silvery fish such as sardines, removing organic matter by ammonia or by digesting with pepsin and acetic acid, and collecting the guanine crystals which cause the fish scales to glimmer. These are mixed with an organic solvent such as acetone. After coating the glass beads from inside, they are left for some time for the solvent to evaporate, leaving behind the dried essence. The beads are then filled with molten wax, cooled and strung on a silk or nylon string.

34 Silk in the Sea

In clouded depths below, the Pinna hides,
And through the silent path obscurely glides;
A stupid wretch, and void of thoughtless care,
He forms no bait, nor lays the tempting snare;
But, dull sluggard, boasts a crab his friend,
Whose busy eyes the coming prey attend.

One room contains them, and the partners dwell
Beneath the convex, of one sloping shell;
Deep in the watery waste the comrades rove
And mutual interest binds their constant love.

His closing shell the Pinna suddenly joins,
And twixt the pressing sides the prey confines.
Thus led by mutual aid, the friendly pair
Divide their gains, and all the plunder share.

Oppian *HALIEUT*

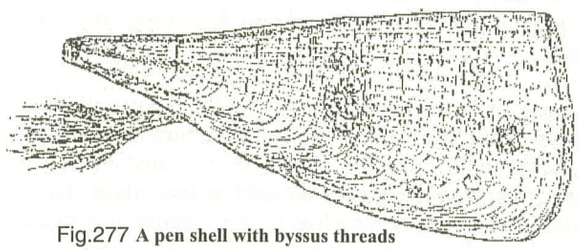


Fig.277 **A pen shell with byssus threads**

These are rather rude lines for an animal that makes the finest silk in the sea. It is the pen shell (*Pinna*) which buries vertically, apex downward, in sand with only a small portion of the shell jutting out. The two valves of the shell, each up to 30 cm long, are shaped like a narrow wedge because of which it is also called fan mussel or fan-shell, In Australia, it is called razor-shell because the sharp edges can inflict bad cuts on a barefooted walker. But this name is also given to another bivalve shell, Solen.

Fig.278
The pearl oyster also spins byssus threads

While many bivalves, including the pearl oyster, make coarse byssus threads, those from the pen shell are fine and glisten with a bronze sheen. The animal secretes a fluid which hardens on contact with sea water to form a soft but strong, tough, elastic fibre called byssus thread, used to anchor the shell.

In the Mediterranean Sea, the pen shell grows to a little under. a metre in length, and its byssus may be up to 30 cm long. The byssus has been spun and then woven into cloth-of-gold from the second century A.D. The fibre was washed and carded with iron combs. It was then made into cloth-of-gold. The cloth is so fine that a pair of gloves can fit into a matchbox, while a shawl can be drawn through a finger ring.

Sea silk is said to have originated at Colchis, an ancient kingdom near the Black Sea. Colchis is also the name of the Golden Fleece which, in Greek legend, Jason and his Argonauts sought. Hence it is quite likely that Jason was after byssus threads.

As availability of byssus thread could not meet the demand for it, like the Tyrian purple dye it became a prerogative for rich and aristocratic people. The Roman Emperor gave robes made of lana Pinna (pen shell wool) to the five hereditary governors of Armenia as insignia of their office. Today, knitted gloves and small cloth items of byssus are sold to tourists in southern Italy.

Pen shells also make irregular pearls. But some of these are black and smooth, and were once in great demand in India. But they break easily when dry.

Coming back to the unflattering poem. A pea-crab inhabits pen shells. Ancients believed that, when a bivalve's prey (small fishes) entered the gaping shell, the pea-crab pricked the tender side of the host as a signal for it to close its shell.

The crab and the bivalve then shared their captured food. Alas! It is far from the truth. The pen shell gathers its food by sieving water over its gills. While oxygen is extracted for breathing, tiny food particles are filtered out, formed into a sticky thread which slowly moves towards the mouth. The pea-crab takes up its position on the host's gills and shamelessly partakes of the food.

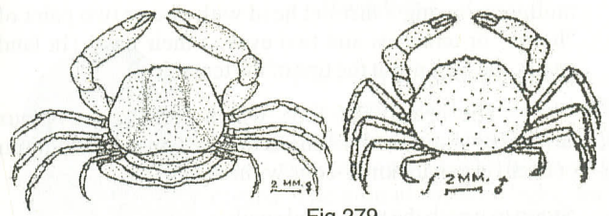


Fig.279
The pea-crab which the author discovered; (left) female, (right) male

During my chequered career I have been fortunate to discover five completely new kinds of crustaceans–three of them crabs. Inventions and discoveries are normally attributed to a little inspiration and a lot of hard work (perspiration), but I shall add to these two qualities that of serendipity. One of my new discoveries was a pea crab living inside clams. It happened this way. My laboratory assistant purchased some clams from the fish market. When his wife opened them to extract the meat, she found "bugs" in many of them and soundly rebuked him for bringing bad stuff. They would have thrown them away, and that would have been the end of it. But his curiosity was aroused; how could there be "spiders" inside clams? As he had no preservative such as formaline or alcohol, he put the 'bugs' in some methylated spirit which was in the house for starting Primus stoves, and brought them for me next day. It took me some five months, but the labour was worth it; the crabs turned out to be a new species!

35 Backpackers of the sea

Did he stand at the diamond door
Of his house in a rainbow frill?
Did he push, when he was uncurled
A golden foot or a fairy horn
Thro' his dim water World?
Tennyson

The snails or Gastropods are well known to everyone from their pretty, coloured shells. They are more highly evolved than bivalve molluscs, having a distinct head with one or two pairs of "horns" or tentacles and two eyes at their base. (In land snails, the eyes are at the tips of the tentacles.)

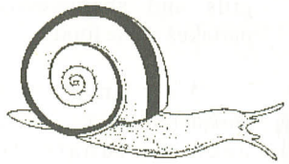


Fig.280 **A typical gastropod snail**

The broad, flat foot, which secretes a copious amount of slime, enables snails to crawl on the sea bottom or even on a sharp knife-edge without harm.

Stoop to watch the tube-eyed snail
Creep o'er his long, moon-glittering trail.

With the slime, they can also stick to rocks. A horny, ribbon-like tongue, with numerous (sometimes as many as 750,000) minute teeth on it, called radula, is used like a rasp to scrape off algae for food and to tear food into smaller pieces in herbivorous snails and to drill holes into bivalve shells in carnivorous snails. If the teeth in front get worn out, they are replaced by teeth at the back moving forward to replace them (just as in sharks).

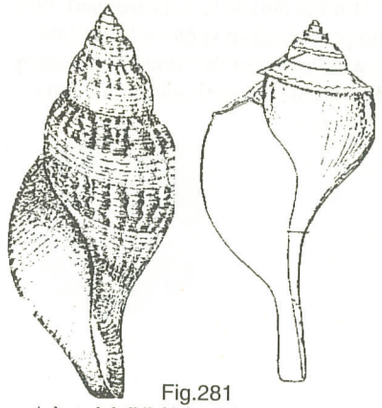


Fig.281
A dextral shell [left] & a sinistral shell [right]

There is usually a hard shell made of calcium carbonate extracted from sea water. It may be a simple cone, but is usually spirally twisted into coils which may be flat, or long and tapering. The whorls of the shell, except the last or body whorl, form the spire; its top is the apex and the opening from which the animal extends is the mouth or aperture of the shell. The margin of the shell mouth is sometimes notched or grooved into a canal. Most snail shells are dextral (right-handed), i.e., when you hold the shell with its mouth facing you, the spiral runs from left to right Left-handed shells are called "sinistral" (e.g., *Busycon perversum*). The outer lip of the shell mouth (on the right in dextral shells) is the labrum. The columella is the axis around which the spires twist. The line joining the adjacent whorls is the suture.

Says Frank Lloyd Wright: We should learn from the snail; it has devised a home that is both exquisite and functional.

Many snails have a "lid" or operculum to close the shell mouth after the animal has withdrawn into it.

Give but his horns the slightest touch,
His self-collecting power is such,
He shrinks into his house with much
Displeasure.
Cowper

The operculum is carried on the top rear portion of the foot, and prevents enemies from taking the snail out of its shell for devouring it. It also hermetically seals the mouth of the shell, so that the snail can hide securely inside, a little water retained within the shell sufficing for respiration.

Within that house secure he hides,
When danger imminent betides
Of storm, or other harm betides,
Of weather.
Cowper

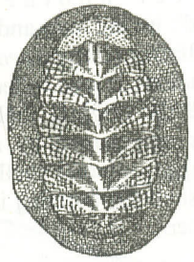


Fig.282
Coat-of-mail shell

The most primitive molluscs are the coat-of-mail shells (*Chiton*). Here the shell consists of eight transverse plates on the back surrounded by a muscular girdle. The shell plates contain many minute pores in which are primitive eye-spots and sense organs. The animal dislikes light, and is found in rock crevices. When disturbed it rolls into a ball like an armadillo.

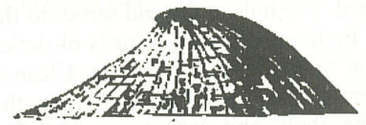
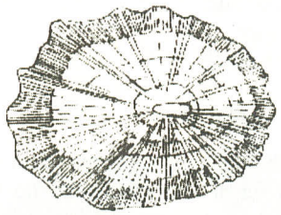


Fig.283 **Limpet [side view]**

Among the gastropods, the most primitive are the limpets (*Patella*). These, like the chitons, are symmetrical; the coil of the shell develops only in more advanced snails. A limpet has a 3 cm conical tent-like shell ending in a sharp point. Below it is the soft body with a muscular foot. It makes its home on a rock. At night, when covered by water they crawl in search of food, which are encrusting weeds on rocks. It rasps them with the long radula (tongue) which is thrice as long as the animal itself and may have over 1,900 minute teeth arranged in more than 150 rows. The animal may wander a few metres away, but before dawn it returns to the same spot on the rock from where it had started and which, in fact, is its home. Over the years, this spot forms a shallow depression in which the shell margin fits closely. When alarmed, it clings so tenaciously to the rock that it requires a force of over 3 kg to dislodge it. Yet, gulls and oyster-catchers (birds) can pry it off with a sudden deft sideways blow with their beak when the limpet is relaxed. Sarah Hoare, in "Poems on conchology and botany" (1831) has one on the limpet:

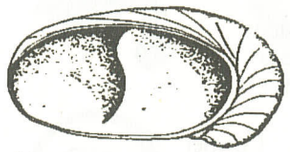
Patella to the rock adheres,
Nor of the raging tempest fears
The most tremendous power;
And though assail'd on every side,
Close to her guardian will abide,
Her strength, her fortress, and her pride,
Her never failing tower.



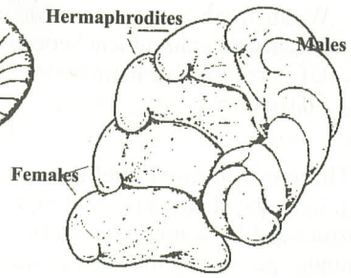
Keyhole limpet (top view)

Keyhole limpets (*Fissurella*) have a slit or hole on top of the shell which is a sort of drain from which its faeces are washed away by the outgoing water current created by the animal for its respiration.

Because of their shell shape, *Crepidula* are called slipper limpets, but they differ from common or keyhole limpets. There are males, females as well as hermaphrodites (individuals with both sexes), and they are often found clumped together, with the smaller males at one end, the hermaphrodites in the middle, and the larger females at the other end.



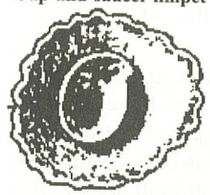
Slipper limpet [after Tyron]



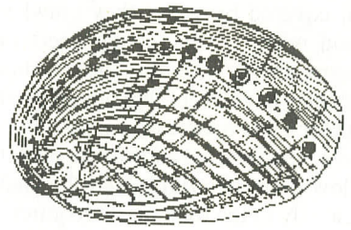
Clump of slipper limpets with sexual graduation according to body size

Yet another "limpet" is the cup-and-saucer limpet (*Calyptraea*, *Crucibulum*). It is so called because the original shell spire is represented by a cup-shaped, internal shell, with the shell surrounding it like a saucer.

Cup-and-saucer limpet



The ear-shell (*Haliotis*) looks like a human ear. The shallow shell has a series of holes near the left border, all of which except the last one are closed. The hole at the end serves to flush water, which is circulated by the movement of tufts of delicate tentacles on the edge of the mantle. Clean sea water enters through the largest two or three holes in the shell, and sensory organs in the animal's mantle cavity constantly check the sea water for food and predators. This cavity also contains the snail's breathing organ (gill). Oxygen-depleted seawater and body wastes are thrown out through the other three holes in the shell. On the outside, the shell looks weather-beaten, but its inside has a beautiful iridescent pearly sheen. The muscular foot helps to attach firmly to rocks. It grows only to a few centimetres on our shores, but in America, where it grows to over 20 cm and is known as abalone, it is a gourmet's delight in the form of abalone steaks (its muscle). Curiously, in Australia it is known as mutton-fish.



Ear shell
Fig.284

Fig.285 **Top shell**

Top shells (*Trochus*) are conical like the old-fashioned whirling peg-top (toys), being about 4 cm high and of the same diameter at the base. A thin, horny operculum is present; it has a pattern of concentric circles.

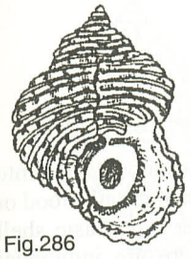


Fig.286
Turban shell with cat's eye [operculum] at mouth of shell

Turban snails (*Turbo*) have a globular shell as if a turban has been wound into a coil. The operculum is hemispherical, its flat portion having the pattern of a spiral etched on the inside, while the convex portion is on the outside when the animal withdraws into the shell. These opercula are known as cat's eyes.

Both top shells and turban shells have a nacreous pearly shell covered by a thin outer layer called periostracum. When the latter is removed, the full beauty of the shell is revealed. Before plastic shirt buttons came into vogue, "pearl" buttons were cut out from these shells. Our coastal top shells and turban shells are quite small, but those in the Andaman Sea are huge, and they were polished (by removing the periostracum) and made into souvenirs, curios and knicknacks like flower vases, *agarbati* (incense stick) stands, ash trays, paper cutting knives, brooches, etc. Collection of these large shells is now restricted.

Of pearly hue
Within, and they that lustre have imbibed,
In the sun's palace porch, where, when unyoked,
His chariot wheel stands midway in the wave.

Walter Savage Landor

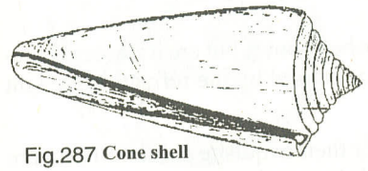


Fig.287 **Cone shell**

Cone sea-shells are prettily coloured and daintily shaped, and have therefore attracted the attention not only of shell collectors but also of poets:

What hides thou in the treasure-caves and cells,
Thou hollow-sounding and mysterious main:
Rare glistening pearls, and rainbow-coloured shells,
Bright things which gleam unrecked of, and in vain.

Felicia Hemans *THE TREASURES OF THE DEEP*

ALSO

See what a lovely shell, small and pure as a pearl,
Frail, but a work divine, made so fairly well,
With delicate spore and whorl, a miracle of design.

Fig.288 **Egg-capsules of Conus**

Cones lay their eggs in flattened, vase-shaped capsules.

One of the daintiest shells is the Button shell or Rosary shell *Umbonium vestiarium*, a relative of top shells but with a flattened shell some 6 mm in size. With spots and stripes across the shells, they vary from white and pink to grey and chestnut brown. They can be found in thousands on sandy beaches, and were earlier collected and exported in huge quantities to cover jewel boxes.

He furnishes his closet first, and fills
The crowded shelves with rarities of shells:
Add orient pearls, which from the wave he drew,
And all the sparkling stones of various hues.
Dryden

The pretty colouration of gastropod shells is due to pigments incorporated into the calcium carbonate of the shell. These pigments are derived from the snail's food or are absorbed as chemicals directly as elements from the seawater. The basic shell colours and patterns remain the same for each species, but there are individual variations in colour shade/intensity and in pattern size/location. Some of this variation is related to availability of food.

The mantle, the thin layer of tissue that lines the inside of a mollusc shell secretes the protein matrix that binds the calcium carbonate crystals and also the calcium carbonate. These materials thicken the shell when deposited on the inside and enlarge the shell when deposited on the edges. The pigment to be incorporated into the shell is first concentrated in the cells along the edge of the mantle. If all the mantle-edge cells secrete pigment, the shell will have a uniform colour. But, if only a few cells secrete pigment and do so throughout the life of the animal, a distinct stripe of colour will be laid down across the shell. If pigment-secreting cell switch on in new locations, the shall design will appear blotchy.

Some shells do not have the flat colours described above, but are iridescent blue-green This is not due to pigments in the shell, but is caused by the refraction of light between the layers of calcium carbonate crystals.

Button shells are not the only ones known for their exquisite colours. There are so many of equally pretty shells of diverse hues and shapes; they have been compared again and again with flowers. Philibert van Borsselen made such a comparison in his *Strande* (*The Beach*) in 1614.

The blue of hyacinths, the lily's snow,
The pansy's yellow, and the purple glow
Alluring feature of the blushing rose,
The rainbow iris, yea not one of those,
Though brilliant and aglow their colours be,
Yields in perfection to shells of the sea.
Even the exotic tulip's varied hue,
Their white aflame with red, their long-sought blue
At last attained, their blazing cloth of gold,
Their marbled pattern, and the graceful mould
That robes them cannot vie with the sea shells.
Here gold and silver thread sheer miracles.
Here shimmers sky-blue, here black counters white,
Here yields the sun his gold, the moon her light,
Here glitters starlight, yonder glides the dance
Of the wild ocean, here the tides advance
And there recede, while in the deep below
Sun, moon, and stars and sea make the shells grow.
From *Strande* (*The Beach*), 1614

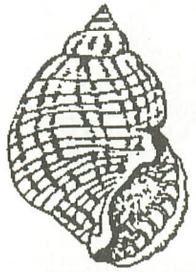


Fig.289 **Periwinkle**

Periwinkles (*Littorina*) are quite resistant to drying. The long conical shells of some of them are found well above the high tide mark, where the water would never reach them; only the spray from splashing waves wets them, but this seems to be sufficient for them.

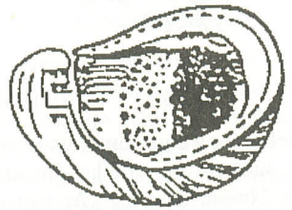


Fig.290 **False periwinkle**

False periwinkles (*Nerita*) live just below high tide level, where they are tumbled by waves. To cope up with this, the shell is massive. Though it shows spiral markings outside, the columella and whorl partitions are absent inside, so that there is only one rounded cavity to house the animal. The half-moon shaped operculum has a finger-like projection which locks with the lip of the shell.

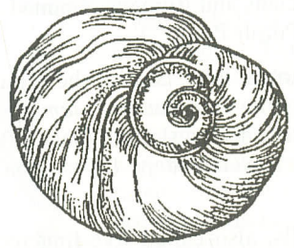


Fig.291 **Moon snail**

Moon-snails (*Natica*) have a thin, globular shell, light in weight, and are found in sand. The foot is huge, so that the shell is almost completely covered when the foot is fully extended, and its front is turned up like a shield in front of the head. Using this foot to plough just beneath the surface, it searches for bivalves. When it comes across one, it drills a hole in its prey's shell valve and devours it. It also feeds on dead molluscs and fishes if it comes across them.

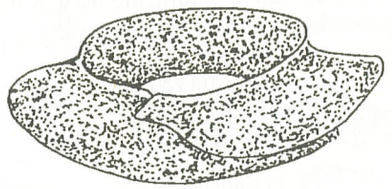


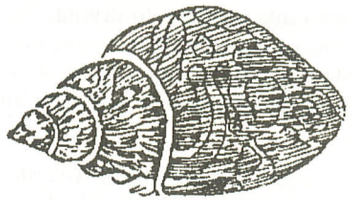
Fig.292 **Egg capsule of moon snail**

The egg-cases of moon-snails, and their allies *Uber* and *Polinices*, are unique. They look like flat, leathery collars and are quite common on mud flats. Seen against light, we can discern thousands of tiny eggs interspersed with sand grains glued together to form a curved strap. Some *Uber* snails in coral reefs lay an exquisitely patterned egg mass truly a work of art and a thing of beauty.

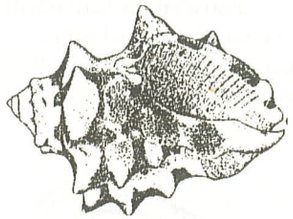
The drilling by moon snails (*Natica*, also called shark-eyes or tiger-eyes) is effected by both chemical and mechanical means. They drill holes in shells by alternately applying an accessory boring organ, which produces an acid secretion containing an enzymatic softening agent (carbon anhydrase), and scraping the shell with their radular teeth. Penetration of the shell is slow and may take several days to accomplish.

Murices (*Murex* and its relatives) attack barnacles, gastropods and bivalve shells in the same way, using their radular teeth to grasp the prey after the shell is excavated. The drilling dogwhelk (*Nucella*) avoids drilling through the victim's shell by attacking its joints and injecting a relaxing toxin which makes the opercular plates gape.

Some species of octopus also drill holes in molluscs with their radular teeth.



Whelk [*Babylonia*]



Purple [*Thais*]

Spider shell or murice [*Murex*]

Fig.293

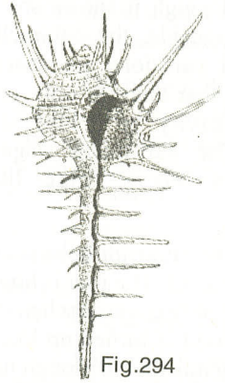
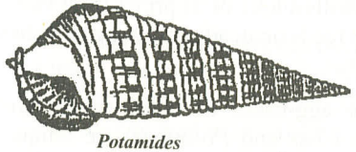


Fig.294
Venus's comb shell

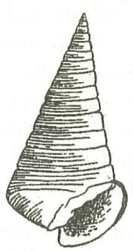
Whelks are a conglomerate of several familiar families and genera, such as the whelks: Buccinidae, e.g., *Babylonia*; dog-whelks: Nassaridae, e.g., *Nassarius, Arcularia*; purples: Thaididae, e.g., *Thais, Drupa, Rapana*; and spider-shells: Muricidae, e.g., *Murex*. They too are carnivorous and of fairly large size. Like moon-snails, they drill holes in the shells of bivalves and feed on the animals. From some of the murices and purples, the ancient Phoenicians and Romans obtained a dyeTyrian purple. (See chapter "Purple Pomp".)

With similarly shaped narrow, long, conical shells but belonging to different families are the horn shells (*Potamides*, *Telescopium*), beak shells (*Tibia*), screw shells (*Turitella*), auger shells (*Terebra*), wentle-traps (*Epitonium*) and mitres (*Mitra*).

Scorpion shells, also called five-fingered chanks (*Lambis*) are used as sinkers for nets and for catching octopuses which, in turn, are used as bait for catching seerfish, dogfish and sting rays.

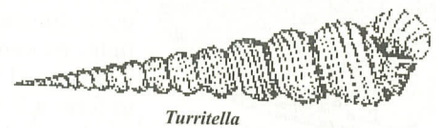


Potamides



Telescopium

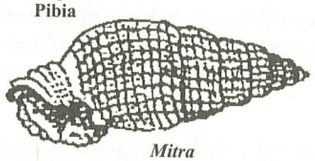
Pibia



Turritella

Terebra

Fig.295 *Epitonium*



Mitra

The sacred chank (*Turbinella pyrum*) is well known, as it is blown as a trumpet in temples, being regarded as one of the emblems of Vishnu and held in one of his hands. The normal shell is dextral (right handed), but the rare sinistral (left handed) form, known as *Dakshina varta*, is in great demand by superstitious people as it is believed to bring fortune and riches.

Fig.296
Sacred chank

Many people are fooled into paying high prices for the American *Busycon contrarium* which is normally sinistral being palmed off on gullible folks as the "lucky" sinistral sacred chank, even though the two can be readily distinguished.

Apart from the carved and ornamented "Mazza" used in Hindu, Buddhist and Jain temples, the chank is used in Sri Lanka to contain the holy oil for anointing priests and administering their medicines.

In Bengal and Bangladesh, at places far from the sea coast such as Dhaka and Dinajpore, the round body whorl of the chank is cut by crescentic saws into bangles, which are a 'must' for a Bengali bride. Left-over scraps from bangle manufacture, called Ghara, are made into beads at Murshidabad and the dust was converted, when small pox was rampant in India, to a paste used to prevent pitting of the skin in smallpox victims. The scrap is also used as gravel in temple gardens. The soft animal removed from the shell, is sold to Kavirajs (medicine men) for use against spleen disorders.

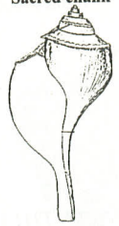


Fig.297
Busycon

It is restricted to Indian seas, occurring nowhere else. The snow-white shell is covered in living forms by a velvety, golden-brown periostracum. Found in Gujarat, Gulf of Mannar (Tamil Nadu) and the Andaman Islands, it is gregarious and feeds on tube-dwelling worms. It has a bizarre life history. In winter the female lays a twisted egg-mass, 18 to 25 cm high, made of many capsules and anchored on the sandy sea bottom. Each capsule contains many eggs embedded in a common jelly. The larvae, called protoconch, eat up their neighbours in the capsules until only about half a dozen remain in each capsule. The remnants then eat the partition walls of the capsules until some 200-250 young, each 12 mm long emerge.

Fig.298 Egg case of sacred chank

The worm-shell (*Vermetus*), when young, has a regularly coiled shell and creeps about on the sea bottom. It soon attaches to a rock and the shell now grows as a very loosely twisted spiral as if the animal has forgotten how to make a tight coil.

While most sea shells are covered by an outer horny layer called periostracum, some, like the cowries, olives and harp shells are protected by extensions of the mantle, so that the shell has a highly polished look.

Fig.299
Worm shell

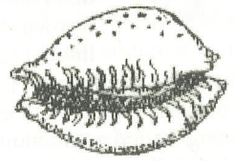


Fig.300
Cowrie seen from below

Cowries (*Cypraea*) have a spindle-shaped shell with a narrow slit below. The brightly coloured mantle flaps are exerted and cover the shell. On being disturbed, these are withdrawn within the shell. Many kinds occur; the small money cowrie (*Cypraea moneta*) was, till recently, used as money in West Africa, or as ornaments and amulets to ward off the evil eye. It was also used as currency in India, its value being 96 cowries for a pie (one-sixtyfourth of a rupee).

The tiger cowrie (*Cypraea tigris*), apart from being used as a support for darning socks, served another quaint purpose. When the Parsees of Bombay wore turbans– not the ones tied around their heads by other Indians but peculiarly shaped pyramidal caps now seen only on statues of patriots such as Sir Pherozeshah Mehta or Dr. Dadabhoy Naoroji and other eminent personalities of that community, and rarely

at Parsee weddings and important religious functions, and also immortalised by Rudyard Kipling as being worn by Pestonji Bomanji in his story of how the rhinoceros got his skin folds, the cowrie shell was used to polish the turban cloth by rubbing it with coconut oil.

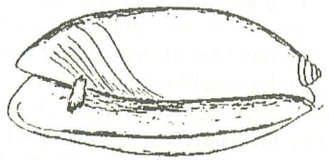
Shuttle shell

The smaller (25 mm) *Ovula* lives on the branches of sea fans, each having the same colour as its host. But the colour is only on the mantle, the shell being white. Shuttle shells (*Volva*) are much larger (85 mm).

Heaven on her shape such cost bestowed,
And with such bounties blest,
No limb of hers but might have made
A goddess at the least.

Thy colours I devis'd with care,
Which were unknown before:
Which since that in her braided hair
The nymphs and sylvans wore.

Michael Drayton *THE QUEST OF CYNTHIA*

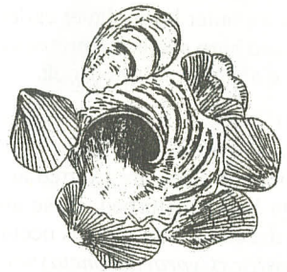


Olive shell

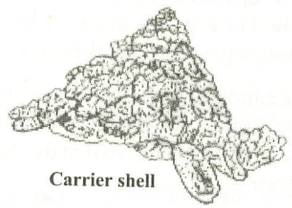
In olives (*Oliva*), the shell is an elongated spindle with a short conical spire and a long narrow mouth. The mantle folds meet over the back to keep the shell polished. Olives are carnivorous, feeding on bivalves.

Harp shell

The prominent longitudinal ribs on the shell, resembling the strings of a harp, give the harp shell (*Harpa*) its name. When threatened, it breaks off the hind portion of its large foot. The shell is kept in a state of high polish by the mantle folds.



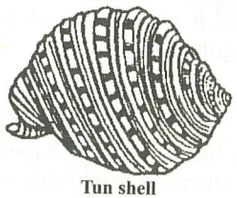
Carrier shell with attached shells



Carrier shell

The carrier shell or grotto shell, also known as Indian Phorous (*Xenophora solaris*), in an attempt to camouflage itself, sticks other shells or stones on its own shell at the spiral line of growth, so that these do not interfere in its movements. Each variety has its own choice of material to be attached, those using stones and coral being called mineralogists, while the "conchologists" prefer shells.

Similar in shape are the staircase shells, also called sundial shells (*Architectonica*).

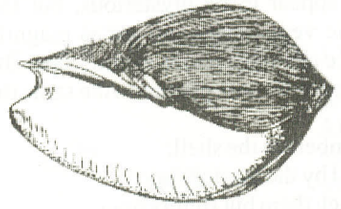


Tun shell

Fig.301

Two pretty shells which are quite light in weight and frail are the tun-shell (*Tonna*), having a globular body with many narrow ribs and a wide body whorl, and the melon shell (*Melo*). In Burmese, tun means light in weight. The melon shell is a pretty pale orange-yellow with irregular rows of brown blotches.

Egg cykinder of melon shell



Melon shell

Fig.302

Fishermen use it for bailing out water from a boat. Its large (30 cm high) egg mass looks like a glassy honeycombed pineapple with a narrow cavity in the centre of the cylinder. The mother carries the egg mass on her back until the young emerge. As in the sacred chank, each capsule in the egg mass has numerous eggs, but cannibalism is rampant and only one 2–cm long young comes out of each capsule.

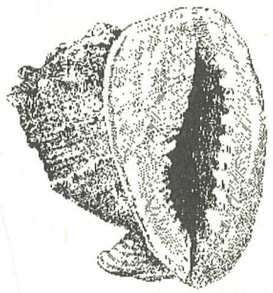


Fig.303 Helmet shell

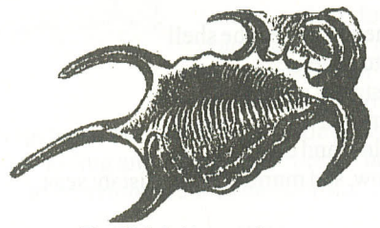


Fig.304 Spider conch

At the other end of the spectrum are the massive helmet shells (*Cassis*). Their shells have differently coloured layers, as in cowries, and are used in Italy to make cameos of a white figure on a purplish background. The lips of the shell mouth are thick and expanded to form a flat undersurface with a wide slit in between.

Also massive are the spider conches (*Lambis*), so called because of the seven channeled finger-like extensions on the outer lip of the shell.

When an empty sea shell is held against our ear, a murmur like waves beating on a seashore can be heard. This inspired William Wordsworth to pen the following poem:

I have seen
A curious child apply to his ear
The convolutions of a smooth-lipped shell,
To which, in silence hushed, his very soul.
Listened intensely, and his countenance soon
Brightened with joy, for the murmuring from within
Were heard sonorous cadences whereby,
To his belief, the monitor express'd
Mysterious union with its native sea.

A shorter one by Rossetti conveys the same thoughts:

Gather a shell from the strown beach
And listen at its lips: they sigh
The same desire and mystery,
The echo of the whole sea's speech.

And yet again, this one by Walter Savage Landor:

Shake one, and it awakens; then apply
Its polished lip to your attentive ear,
And it remembers its august abode
And murmurs as the ocean murmurs there.

The sound of waves might appear to be mysterious, but the explanation is simple. The coursing of blood in the veins inside our ear is magnified by the large volume of air within the shell. It is like a crude doctor's stethoscope. But it has captured so many poets' imagination; below are a few more poems on the same theme.

The soul of music slumbers in the shell,
Till waked and kindled by the master's spell;
And feeling hearts touch them but rightly pour
A thousand melodies unheard before.
Samuel Rogers

And then I pressed the shell
Close to my ear
And listened well,
And straightway like a bell
Came low and clear
The slow, sad murmur of far distant seas.

AND

Less than a God they thought there could not dwell
Within the hollow of that shell
That spoke so sweetly.

36 Stingers on the Shore

How many arrows under his right side,
All deadly dangerous, all cruel keene,
Headed with flint, and feathers bloody dyed,
Such as the Indians in their quivers hide.

The sea-shells that people so avidly collect for the beauty of their colour and shape are the empty "houses" in which dwelt soft animals. These snails, like the proverbial tortoise, move very slowly, and are either vegetarians or scavengers feeding on carrion. One group of snails, however, has adapted to killing and eating faster prey. These are the cone shells, and they have evolved a style more reminiscent of the scorpion or the cobra. And some of them can kill human beings.

Cones have been known for ages to be dangerous to man. As early as 1705, the Dutch naturalist G. E. Rumphius reported the death of a woman on the island of Banda, in Indonesia. She picked up a live cone shell and held it clenched in her fist. She felt a tickling in her palm, which sensation crept slowly through her body. Within minutes she was dead. The cone shells most often responsible for human deaths are the geography cone (*Conus geographus*), the tulip cone (*C. tulipa*) and the streaked cone (*C. striatus*). All are fish-eaters.

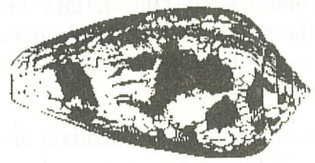


Fig.305 **Textile cone (*Conus textile*)**

There are more than 400 kinds of cone shells. They abound in the tropics, mainly in the Indian and Pacific Oceans, from shallow water down to a depth of several hundred feet. Some cones grow to 23 cm. They are appropriately named, having heavy shells shaped like a truncated cone. The spire, unlike in other shells, is quite flat. Many cone shells, because of their great beauty of colour and design, are collectors' items. Some of them can be quite expensive. One of the rarest is *Conus gloriamaris*. As late as 25 years ago, only 70 specimens of this Glory-of-the-seas were known, and fetched a price of over Rs.18,000 each and were once worth ten times their weight in gold. A spceimen in the British Museum was bought for £70. A Frenchman had the first, and at that time the only, specimen of this cone shell. When a second one was found he purchased it, and promptly crushed it into fragments so that he could claim to possess the only one in the world.

Cone shells feed on three types of prey– other molluscs (snails, clams and octopuses), worms or fishes. The prey is killed by a potent venom injected into it, and the poison is so specialised that it will have an effect only on prey animals of its particular group. Thus a snail-eater, like *Conus textile* or *Conus marmoreus*, will kill snails but not fish. The venom of fish-eaters, such as *Conus geographus*, will not kill worms or snails, and that of worm-eaters will not kill fish. The poison may be still more specialised. Of two kinds of worm-eating cone shells inhabiting the same beach, one could kill only nereid worms and the other only eunicid worms. Out of seven kinds of worm-eating cone shells, only three could kill a common marine worm, *Phyllodoce*. One cone shell, *Conus marmoreus*, feeds only on other species of cone shells.

Although all cones are venomous, only the fish-eating species are deadly to humans. The cat cone (*C. catus*) is also a fish eater and hence potentially dangerous. The textile or tent cone group, including the common textile cone (*C. textile*), the court cone (*C. aulicus*) and the episcopal cone (*C. episcopus*) were previously thought to be deadly to humans, but they are mollusc-eaters with low-potency venom. (People often confuse the deadly geography cone with the relatively harmless textile cone.)

The venom is contained in tiny darts, 9 to 10 mm long. These darts are derived from the radula or tongue. In most snails, the radula is a flat ribbon on which there are minute teeth like the rasps on a carpenter's file, and the radula is brushed to and fro to scrape off pieces of food. In the cone shells, however, the radular teeth are shaped into elaborately barbed harpoons. These teeth are manufactured in an L-shaped bag called the radular sac. When fully formed, they shift from the long arm of the radular sac to the short arm, which opens into the pharynx (throat) of the snail. By the time the darts reach there, their interior is filled with venom.

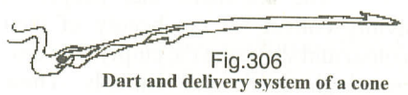


Fig.306
Dart and delivery system of a cone

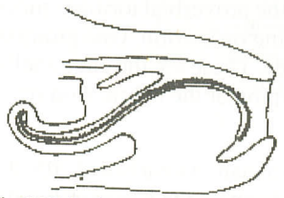


Fig.307 **Section through a snail showing how the radula is lodged inside the radular sac. Mouth is on right**

With Spanish yew so strong,
Arrows a cloth-yard long,
That like to serpent's sting ...
Michael Drayton
THE BATTLE OF AGINCOURT

A single tooth is enough to kill a worm, but as many as six may be shot into a snail. The dart remains inside the prey and passes through the cone shell's gut without harming it. While devouring a snail, the cone presses its mouth against the victim's shell aperture. After holding it for fifteen minutes to an hour the empty prey shell is dropped. Each radular tooth is used only once. If it fails to hit its target, the tooth is ejected from the mouth and a new one moves into position from the radular sheath.

The auger shells (family Terebridae) and turret shells (family Turridae) also possess harpoon-like radular teeth similar to the cones, but their venom is weak and tooth structure relatively undeveloped.

Most cone shells hunt at night. In the daytime they are buried in the sand, or under stones or coral. They can probably smell their prey by means of a "nose" called the osphradium. This nose lies in the path of the water current that is constantly being pumped through the cone shell by its siphon, a tube lying between and above the two tentacles.

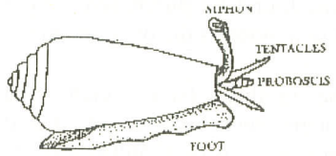


Fig.308
A live cone with its proboscis extended

Fish-eating cone shells do not respond to dead fish. The presence of a live fish, however, makes them active. The snail's proboscis (snout) points in the direction of the fish and stretches till it is almost half as long as the cone shell. The fish swims closer; the proboscis is kept pointed towards it. When the proboscis tip touches the fish, a dart is shot in with force. At the same time, a muscular ring tightens around a bulb at the rear end of the dart, preventing the fish from jerking itself free. By now, the fish has been weakened by the venom. The proboscis shortens, and the fish is "reeled in", as it were.

The cone's mouth now widens enormously (to 2 cm.), like the gape of a snake devouring a rat, and it engulfs its meal. If the fish manages to escape, the dart can be used only once. In this manner, a cone shell 11cm. long can consume a 9-cm. long fish, albeit taking several hours.

Some cone shells are timid and sluggish, and withdraw quickly into their shells when disturbed. Others are quite active and, when picked up, may extend their proboscis to investigate their surroundings. (*Conus textile* is particularly aggressive.) A cone shell can sting only when its head is outside the shell. When collecting cone shells, always pick up the snail by the large hind end of the shell. If you see the snail extending its snout from the pointed front end, drop it immediately. Most stings occur when the shell collector tries to scrape encrusted matter from the cone shell. The scraping action probably stimulates the cone to sting. *Never* hold a live cone shell in the hand longer than necessary, because the snail, even if it has withdrawn into its shell, will soon relax and extend its snout.

37 Purple Pomp

Who has not heard how Tyrian shells
Enclosed the blue, that dye of dyes,
Whereof one drop worked miracles,
And coloured like Astarte's eyes
Raw Silk the merchant sells?

Elizabeth Browning

As you walk along our shores, you may come across a prettily sculptured orange-brown shell. And if you had an entrepreneurial bent of mind and lived in 300 A.D., you could have been a millionaire. For the shell is of the snail *Murex*– a member of a group which yield the famous Tyrian purple dye.

Next to gems and gold, Tyrian or royal purple was the most expensive commodity of the Phoenicians, who lived along the coast of the Mediterranean Sea. In 300 A.D., a kilogram of silk dyed with royal purple cost over two lakh rupees. And no wonder, as 1,30,000 snails had to be used to yield a kg of the dye. The name Tyrian purple comes from Tyre, a seaport west of Damascus, which was the principal city where the dye was processed. The dye was so vital to the economy of Tyre that the shell is depicted on many of their coins. It was obtained from the Banded Murex (*Murex trunculus*), the Spiny Murex (*Murex brandaris*) and the Rock Shell (*Thais haemastoma*). Before them, the people of Crete had discovered the dye as early as 1600 B.C., and by 1000 B.C. Tyre was well known for its dyed wool and silk.

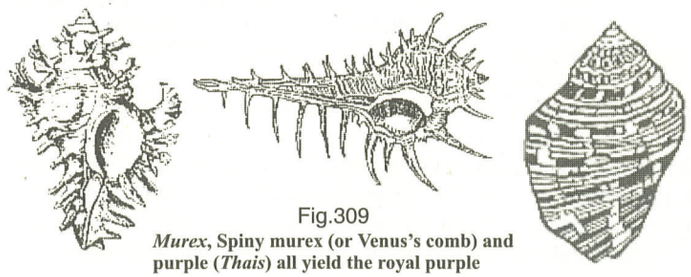


Fig.309
***Murex*, Spiny murex (or Venus's comb) and purple (*Thais*) all yield the royal purple**

The story goes that the dye was discovered accidentally by Melkart, the patron deity of Tyre. He was strolling along the beach with a nymph named Tyrus when their dog bit a live *Murex* snail and got its mouth stained purple. Tyrus liked the colour so much that she told Melkart that she would not be his wife unless he gave her a robe of the same colour. Melkart managed to gather enough *Murex* snails to fulfill her desire, thus winning her love.

The snails were collected by using long ropes, with traps baited with mussels or frogs, at the end of the winter season. A gland, located at the tip of the shell yields just two drops of a yellowish-white creamy fluid. The glands of *Murex* were removed, while Rock Shells were crushed, and 1 kg of salt was added for every 80 kg of the mixture. After allowing it to rot for 3-4 days in the sun, the pulp was kept in lead or tin (but not copper or brass) vessels to which a lot of water was added. Steam was passed through it so as to allow it to simmer gently for ten days, skimming off impurities. 80 kg of pulp would yield 5 kg of the dye. A sample of wool was dipped in it to test the colour, and the whole was heated until the dye attained the proper hue. As *Murex* produces a drab and dark purple, while Rock Shells do not produce a rich and lustrous colour or one which would last, 200 parts by weight of the former were mixed with 111 parts of the latter. To fix the colour of the cloth permanently, a mordant called archil was used. This was made by steeping lichens in stale urine. Or an alkali obtained from a seaweed was used.

In the Roman Empire, royal purple was so much in demand that there was a dire shortage of *Murex* snails. Thus only the rich could afford to wear clothes dyed with it. Later, only senators were allowed to wear it, and finally the cloth was restricted to the emperor. Roman ladies used the dye as lipstick and blusher. When Alexander the Great captured the city of Susa from the Persians, among the loot were more than 13,500 kg of cloth dyed with royal purple. In 638 A.D. Phoenicia was conquered by the Saracens, but the dye making continued, and even in the reign of Charlemagne (768-814 A.D.) merchants of Venice imported it into Lombardy. But thereafter the dye works of Phoenicia were abandoned. And the advent of synthetic aniline dyes in the late 19th century dealt a body blow to Tyrian purple. Yet it was used in the 1700s in Great Britain and western Europe for a much humbler purpose, viz., to mark laundry clothing.

In Japan, dye was made from *Murex* snails, but there too excessive collection must have led to scarcity, as in the tenth century restraints, similar to those by the Roman emperors were observed. In the Americas, shellfish dyes were used in Peru as early as 100 B.C. for cloth in which the dead were embalmed and wrapped. In Mexico, purple colouring matter was used to decorate pottery in pre-Columbian times. And in the 1500s, Spanish conquistadores found native Indians at Nicoya dyeing cloth with shellfish juice. The Mixtec Indians of Central America still use snails to get the dye, but they are more conservation minded; they milk the snails instead of killing them to obtain the dye. The snails are "milked" by pressing on the operculum of a live animal. A small quantity of the white fluid will then be discharged.

The snail has better uses for the dye, which conchologists (people who study snails) call "punicin". It is creamy in colour, with the smell of garlic. It is probably used by *Murex* snails to narcotize the limpets, clams and mussels on which the carnivorous *Murex* feeds. It may also be repugnant to its enemies, as its eggs have a large amount of punicin to ward off potential predators. During the egg laying season, the amount of punicin in the snail's body is substantially reduced– a fact the Phoenicians knew, as they gathered the snails just before the egg laying season.

Apart from the use of its dye, the *Murex* snail was also considered to be of medicinal value. In 18th century Europe, it was used for treating boils, ulcers, tumours and earache. An esoteric remedy was to get rid of spots in front of the eyes! And women believed that if they placed the snail on their navel, they would have many children!

The dye finds its place even in the Bible. In the book of Exodus, Moses is instructed how to furnish the Tabernacle: "These are the contributions you should accept from them; violet, purple and scarlet yarn, fine linen and goat hair." While the indigo plant gives a violet dye, and the madder root a red dye, the "purple and scarlet" yarn was obviously dyed with *Murex* snails. At the naval battle of Actium, Anthony and Cleopatra sailed in a ship whose sails were dyed royal purple. And the Roman writer Lucan tells of Cleopatra appearing at a banquet in a silk dress made in Tyre.

You too can try your hand at dyeing a handkerchief with the dye that was once the hallmark of royalty or aristocracy. Get hold of enough of the secretion from the mantle of our local *Murex* or *Thais* and dab it on a cloth. Do not be disappointed if you see only a

faint creamy-yellow stain on the cloth. Hold it in bright sunlight, and you will see a gamut of colours, changing from yellow to green, blue, red and deep purple. Wash the cloth in soap and water and you will obtain a bright crimson which, moreover, is colour-fast. And do not be chary about displaying it; no one will hang or execute you for defying the ban on pain of death, on wearing a dye which was once a Roman emperor's exclusive prerogative!

38 Gilding the Lily

To gild refined gold, to paint the lily,
To throw a perfume on the violet,
To smooth the ice, or add another hue
Unto the rainbow, or with taper-light
To seek the beauteous eye of heaven to garnish,
Is wasteful and ridiculous excess.

Shakespeare *KING JOHN*

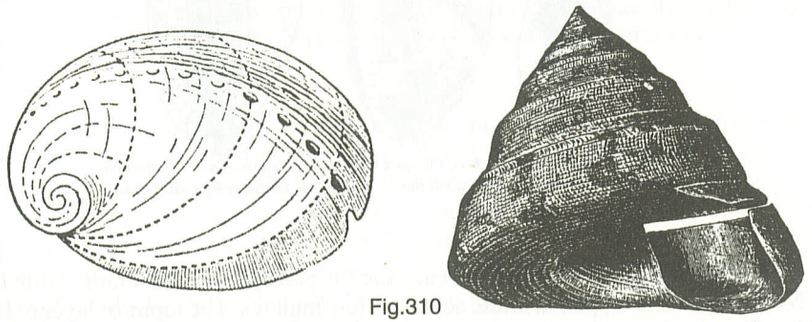


Fig.310

While the inside of the ear-shell (*Haliotis*) (left) has a mother-of-pearl sheen, the outermost layer of the top-shell (*Trochus*)(right) has to be removed to reveal the second (mother-of-pearl) layer

Nature has endowed many of her creatures with beauty. Some, like the coral reef fishes, flaunt it. Others, like a bashful maiden, hide it. Thus top shells, turban shells and nautili have a beautiful pearly sheen on the shell, but this is hidden by the outermost layer of the shell. Only after this layer is removed can the pearly layer be seen. This is routinely done for making shellcraft artictes, and is one of the rare instances where man improves upon nature's beauty.

Fig.311 **A Tiger cowry (*Cypraea tigris*)**

Another popular shellcraft is practised on cowrie and wing shells. As a cowrie shell grows, it deposits layers of different colours. The baby tiger cowrie has a prominent conical spire and a wide-mouthed opening bounded by a sharp lip. The surface of the shell is covered by a dull horny coating, the periostracum. As the cowrie grows, the mantle from each side enlarges and folds over the back of the shell, until the two edges meet. The horny coating is absorbed, and the lip of the aperture thickens. The mantle flaps start depositing enamel-like nacre that extends over the spire and eventually obliterates it completely. The outer lip now turns inward; it and the edge of the inner lip thicken and become furrowed. Finally, the aperture narrows considerably, leaving a short canal at each end. Simultaneously with the change in the shape of the

shell, the colour also changes. At first, the surface is a uniform brown. Next, the colour breaks up into close-set streaks. A white coat is deposited over this, which is again superimposed with zigzag flame-like bands. A second layer of white is now deposited, over which grows another coat with numerous dark spots. Over a final layer of violet is the top, highly polished enamel with black and brown spots.

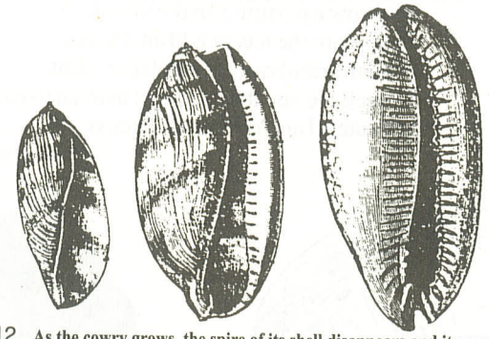


Fig.312 **As the cowry grows, the spire of its shell disappears and its aperture narrows to a narrow slit due to inrolling of the outer lip.(After Cooke)**

To make designs, the cowrie or wing shell is painted with the motif, using oil paint. Next, the shell is dipped in dilute acid for a few minutes. The topmost layer of the shell dissolves in the acid, except where it is protected by paint. The paint is then removed by swabbing with turpentine or kerosene and the shell polished with dry cloth. The artisans are so adept at their work that they can execute orders within ten minutes. Ready-etched shells with religious motifs usually a profile of the famous Rameswaram temple or the Nandi bull are popular with pilgrims who visit the temple. Animal or bird motifs, or personalised designs bearing one's name, are also common.

And what is Art whereto we press,
Through paint and prose and rhyme
When Nature in her nakedness
Defeats us every time.

Kipling

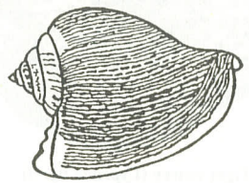


Fig.313 **Wing shell.(*Strombus canarium*)**

Another type of shell etching is carried out by the Sanguvetian Muslims of Kilakarai, using extremely primitive tools on wing shells, which are found in large numbers in the Gulf of Mannar and Palk Bay. This snail has a massive shell with a short, conical spire, and with the outer lip thickened to form a stout wing-like expansion that gives the shell its name. It is an active animal, moving across the sea bottom with leaping movements. When held in the hand, the two prominent stalked eyes have an alert, watchful look, giving an impression of intelligence. It should, however, be handled with caution. It has a cunning habit of lying motionless, then suddenly

wrenching itself free with a quick, unexpected jerk. The narrow, arched foot, armed with a long, claw-shaped operculum (which is used to seal the shell opening), can cause a nasty wound.

The Sanguvettians break the two ends of the shell by hammer blows, and then grind the middle portion laboriously on a stone to make a ring. Only a hammer, chisel and file are used. The rings, known locally as *Sangu modiram*, are worn on the fingers as a cure for skin diseases. In the Malabar and Kanara districts, poor people use these rings to make necklaces for women and children. Because the wing shells have a brown surface coating with a white layer underneath, they too can be etched to form designs.

Unlike the cameos on shells made in Italy and Mediterranean countries by using fine drills and files, the artisan takes a lovely shell and turns it into a beautiful work of art.

Cameo carving is a centuries-old art practiced chiefly in Italy, where the principal centre is Torre del Greco near Naples. Shells of the helmet family (*Cassis*) form the basis for the industry. Helmet shells with a reddish hue come from Mozambique and Madagascar, while those from the West Indies are brownish. Conches (*Strombus*) are also sometimes used. The shells are hard to the touch and require considerable pressure to carve. And they are extremely fragile, breaking easily. Only the area around the lip of the shell can be used for large carvings, but it is the apex of the shell that produces the pieces of finest quality.

Gilding can sometimes be used to cover up a shoddy object, as I once learnt to my dismay. Having donated my blood 109 times, I was often felicitated by different organisations. Once there were eighteen of us who had donated blood over 50 times and were each given a gold ring. It was quite big and heavy, and knowing the price of gold, I surmised that it would not be a gold ring but must have been a gold-plated silver ring. Since I do not like to show off, I put it away in a cupboard.

After some months I got a letter asking me to return the ring as it was "faulty". I examined the ring but I could not find any flaw or blemish. Anyway I returned it after asking what was faulty with the ring. I was shown a trayful of similar rings and told that, unlike me, others had worn the ring and complained within a few months. And what was wrong? The gilding was so thin that the gold layer soon wore off, revealing that the rings were made of iron!

39 Butterflies of the Sea—"Flying Snails"

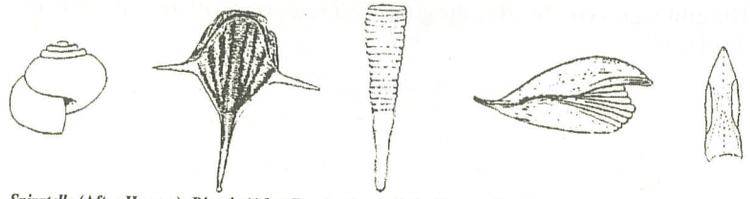
Light as a flake of foam upon the wind,
Keel upward from the deep emerged a shell,
Shaped like the moon ere half her hour is fill'd;
Fraught with young life, it righted as it rose,
And moved at will upon the yielding water.
The native pilot of the little bark,
Spread to the wafting breeze a twofold sail,
And mounted up and glided down the billow,
In happy freedom pleased to feel the air,
And wander in the luxury of light.

James Montgomery *PELICAN ISLAND*

Most molluscs are either sessile or crawl slowly on the sea bottom. When we think of swimming molluscs, squid and cuttlefish come to our mind. But there is another group of snails that lead a life of swimming in the sea. Belonging to the gastropods, they are the Pteropods and their cousins the Heteropods.

Also called sea butterflies, Pteropod snails are beautifully adapted for life in the open water, having their parapodia (foot-flaps) adapted into two fins or "wings" which they flap for swimming. There are two groups; the Thecosomes which have a delicate transparent, conical shell and the Gymnosomes which lack a shell. Under suitable conditions of tides and currents they may gather together in enormous numbers; their presence near the coast is an indication of an influx of oceanic water. When the shelled pteropods (thecosomes) die, their shells sink to the sea bottom to form pteropod ooze. The shells are of various shapes. In *Spiratella* (= *Limacina*), the shell is spirally coiled and has an operculum (lid). In *Diacria*, the upper surface of the shell is ribbed and there are spikes on the sides and at the tip. The shell of *Cavolina* (= *Cavolinia*) is deeply slit on the side. *Creseis* has its shell shaped like a thin, tapering cone, while in *Clione* (= *Clio*) it is a flattened triangle with a wide aperture.

Fig.314 **Shells of the sea butterflies**



Spiratella **(After Hyman)** ***Diacria*** **(After Boas)** ***Creseis*****(After Boas)** ***Cavolina*****(After Meisenheimer)** **False shell o f** ***Cymbulia*****(After Hyman)**

Thecosomes swim ventral side up in a diagonal position, therefore their parapodia are more strongly pigmented ventrally. They often float for hours with their parapodia fully extended. Members of the family Cymbullidae, however, swim in a horizontal position. *Spiratella* swim vertically with the opening of their shell pointing upward until they reach the sea surface; then they sink with their parapodia erected but motionless, repeating their up and down movement. *Cavolina* flap their fins at about 110 beats a minute. Gymnosome (naked or shell-less) pteropods swim with their body vertical.

Thecosomes are nocturnal, and rise to the sea surface at dusk, then moving down at midnight. They are thus absent in surface plankton during the day. Gymnosomes, however, are found in surface waters during the day and do not sink very far at night.

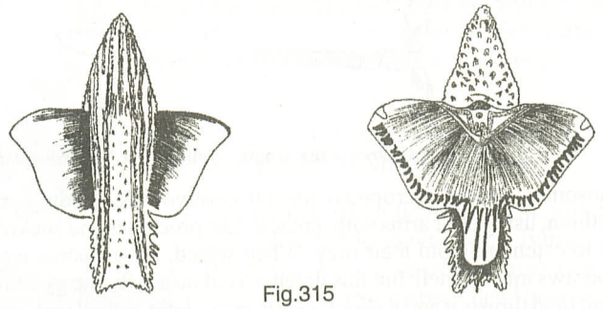


Fig.315

Venus's slipper (Cymbulia), viewed from above (left) and from below (right). (After Vayssiere)

Most pteropods grow to less than a centimetre, but Venus' slipper (*Cymbulia*) grows to 8 cm. Although a thecosome, it has lost its hard shell. Instead it has a gelatinous, knobby false-shell under the skin; this is boat-shaped, armed with denticles, translucent and cartilaginous, and is known as a pseudoconch, which it carries like a hood. The false-shell is easily detached and is often found washed up on beaches in large numbers. *Creseis*, growing to 1·5 cm, has a needle-like shell with two fins projecting from the top. The gymnosome *Spongiobranchaea* grows to 2 cm and has small fins and arms bearing suckers. There are about 35 species of gymnosomes. *Hydromyles globulosa* is common in Indo-Pacific seas and outnumbers all other species. *Clione* (= *Clio*, 35 mm) is the most numerous in the boreal Atlantic Ocean and is fed upon by Greenland whales. *C. limacine* lives in the boreal and arctic seas, while the Antarctic species is *C. antarctica*. But many scientists are of the opinion that both are the same.

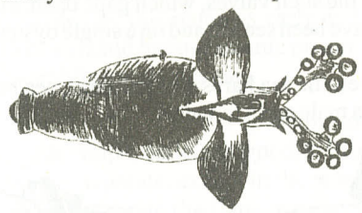


Fig.316 ***Spongiobranchaea*** **(After Pelseneer)**

Thecosomes feed by capturing tiny food particles with their apparatus of cilia (fine hairs). *Cavolina* has cilia all over the rear half of the fins. The median and lateral lobes of the foot form a triangle surrounding the mouth to form three ciliated ridges. The cilia beat in unison towards the mouth and push food to it. *Creseis* has reduced ciliar areas on the fins. *Cymbulia* has these reduced still further, leaving only a ciliated groove running along the front margin of the foot on either side and leading into the mouth. In *Gleba*, the cilia are confined to narrow tracts along the sides of the long proboscis (snout); these lead to ciliary grooves opening directly into the mouth. It does not have jaws, radula (rasp-like tongue) or salivary glands. In *Spiratella*, feeding is carried out mainly by the mantle cavity. The water current enters the mantle cavity from the left. The rim of the mouth has abundant cilia beating inwards. The current passes over an area secreting mucus (slime). The sticky mucus compacts food particles into a string.

From time to time, the radula bites off portions from the string which are then swallowed. Their food comprises diatoms and dinoflagellates. A gizzard helps thecosomes to break the outer skeletons of their food, such as flagellates, Foraminifera, Radiolaria, diatoms, coccolithophores and tintinnoids.

Fig.317 *Creseis*; **actual length 15 mm.(After Meisenheimer)** ,

Gymnosomes (naked pteropods) are all carnivorous, feeding mainly on their thecosome brethren, using their arms with tentacle-like processes and suckers, buccal cones and hook sacs to catch and hold their prey. When seized, a thecosome ejects a stream of slime and withdraws into its shell, but this defence is of no avail. The gymnosome everts its proboscis (snout) and thrusts it and its hook sacs into its victim's shell to devour it.

Members of the family Pyramidellidae also prey on invertebrates– mainly annelids and molluscs. Each predator has usually one prey species, into whose tissues it thrusts its long proboscis to suck its blood and tissues.

The pteropod *Odostoma* hovers near the tube of the tube-dwelling worm *Pomatoceros*. When the worm extends its crown of tentacles out of its tube, the pteropod wraps its everted proboscis around one of the tentacles. The sucker at the proboscis tip slides down the tentacle till it reaches the victim's mouth, when the stylet pierces the worm's body to suck in its blood and tissues. For feeding on a bivalve mollusc, the stylet pierces its mantle. For defence, the victim retracts its mantle and its edges secrete a ridge, but this creates a pocket in which the *Odostoma* lives, attacking the mantle edge repeatedly. The mantle may be retracted right up to the adductor muscle. By this time the muscle becomes so weak that it cannot close the shell valves, which gape open, killing the oyster. As many as a hundred of these snails have been seen in and on a single oyster.

Like their relatives, the sea hares and sea slugs, sea butterflies are hermaphrodites, i.e., an individual is both a male and a female.

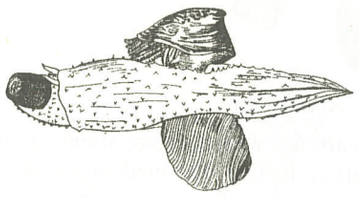


Fig.318 *Carinaria* **(After Vayssiere)**

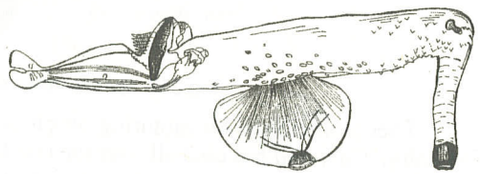
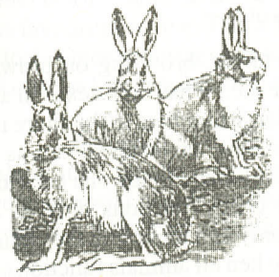


Fig.319 *Pterotrachea* **(After Vayssiere)**

Heteropods are transparent cousins of pteropods, swimming upside down using their fin. Many grow to a whopping 25 cm. Sexes are separate; large suckers on the fins help to hold the partner while mating. *Atlanta* has a flattened spiral shell, of 5 mm diameter, with a wide keel. It can retract its head, with large eyes and long proboscis into the shell. It is purple in colour. *Carinaria* (22 cm) has a much reduced shell from which the gills protrude. It swims with its single muscular fin, and its tubular eyes help it to locate its active animal prey. *Pterotrachea* (26 cm) has lost its shell completely.

40 Quaint Rabbits of the Sea



…. Part single, part with mate,
Graze the sea-weed their pasture, and through groves
Of coral stray, or sporting, with quick glance
Show to the sun their waved coats dropt with gold.

Most sea-snails (molluscs) love to flaunt their pretty shells, but there are some which hide them inside their body and others which have none.

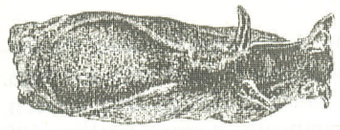


Fig.320 **Sea hare**

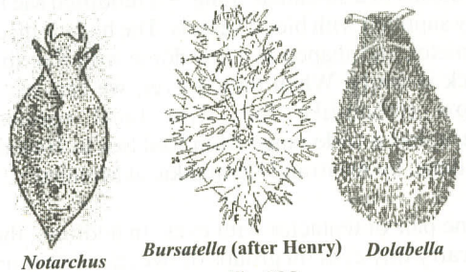
In winter, when the tide is out, you will see soft, jelly-like, bottle-green blobs lying on the shore. When the water comes in at high tide, they extend their body, with a distinct head bearing two pairs of tentacles and a pair of eyes, and a ploughshare-like foot. They are sea-hares; while the more prevalent scientific name is *Aplysia*, some American and Australian malacologists (people who study snails) prefer to use the name *Tethys*.

One of the earliest descriptions of a marine animal in India is of sea-hares. It dates back to *Observations made on a tour made from Bengal to Persia in the years 1786-87,* in Pinkerton's voyages and travels, published in 1811. On page 236 is a statement by Ensign W. Francklin; "the most remarkable animal curiosity the island"– he refers to Bombay– "produces is a small fish … about four inches long, [having] upon the top of its back and near the head, a small valve on the opening of which you discover a liquor of a strong purple colour which when dipped on a cloth, retains the hue".

The sea-hare was also known by this name as early as 1800 years ago, but the ancient Greeks considered it to be evil and having satanic power. The name comes from the long tentacles on its head resembling a rabbit's ears.

Fig.321 *Aplysia*

On the smooth, domed back is a pair of flaps, called parapodia. In *Aplysia*, these are quite separate, except in the rear, where they meet. If we separate the flaps, we can see a small hole, below which is the thin, transparent, papery, fragile shell. In *Notarchus*, a related sea-hare, the parapodia are reduced in size, so that they leave only a short slit between them. It can fold its parapodia around its body to form a chamber which, when contracted, emits a jet of water forward, so that the animal darts back like a squid. There are a few short papillae on the back. The narrow foot enables it to climb seaweeds. A shell is absent.



Notarchus *Bursatella* **(after Henry)** *Dolabella*

Fig.322

Bursatella is "hairy", having its back covered all over by soft projections. It too has no shell and the opening on the back is a slit. *Dolabella* is much larger than the

others, and is much broader behind than in front. It has its back covered with warts. The shell is white, limy, hard, flat and has a deep notch at the rear. The parapodia are broad, touch in the middle line and are often interlocked, leaving an opening in front, and another behind from which the water, after breathing comes out.

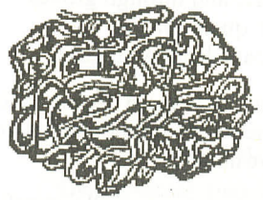


Fig.323 **Egg-string of *Aplysia***

The sea-hare is a vegetarian, browsing on brown seaweeds. It is a hermaphrodite, i.e., it has both sexes in an individual. Sea-hares come in large numbers to the shore in winter to breed. They mate in chains; each animal acts as a male to the one in front, and as a female to the one behind. Thus the first sea-hare in the chain functions only as a female, while the last one acts only as a male. But the chain sometimes closes into a circle, when all animals function as both sexes.

The eggs are laid in the form of a yellow string. As they are extruded, the sea-hare grasps the egg string in a fold of the upper lip and moves its head back and forth. The result looks like a tangled ball of yellow twine. In *Dolabella*, the egg string is green. Sea-hares are prolific breeders. *Aplysia* can lay, intermittently, a string totalling 600 metres, having some 475,000,000 eggs. There may be as many as 145 million eggs at one laying.

As seen earlier, when irritated, *Aplysia* emits a dark purple fluid. This is not similar to the Tyrian purple dye obtained from the sea-snail *Murex*. The fluid is called aplysiopurpurin. It is emitted along with a viscous foul-smelling milky secretion, which may act as a deterrent to predators, as sea-hares seem to have few enemies. However, a sea-anemone is known to ingest young sea-hares.

Fig.324 ***Elysia***

The false sea-hare *Elysia viridis*, has swimming flaps (parapodia) like *Aplysia*, but it lacks an inner shell. The sides of the body are expanded into wing-like lobes (the parapodia), which are folded over the body when the animal is creeping, but are erected and flapped for swimming. It too is a vegetarian; while feeding it punctures the filaments of green seaweeds and sucks out the contents. The body, which is emerald-green, helps it to hide among seaweeds. Unlike *Aplysia*, it has no gill, oxygen being absorbed from the water through its skin.

Fig.325 ***Onchidium***

While several sea-hares have a hidden internal shell, *Onchidium* has none. They breathe by means of a so-called "lung"– a modified sac in the mantle-cavity richly supplied with blood vessels. The body is disc-like, about 3 cm in diameter, and shaped as a low dome with flat rim. The sand-coloured back is warty. When turned over, we can see a cream-coloured narrow ribbon-like foot. Our local species, *Onchidium verruculatum*, has a wide range from Red Sea to Hawaii and has been studied in detail by Awati and Karandikar at Mumbai.

There is only one pair of tentacles with eyes. In addition, the warts on the back also carry tiny eyes, in groups of two, three or four. The warts are retractile, like a submarine's periscope, when touched. Unlike other Onchidiums, our species has some branched papillae (gills) in the rear on the back.

Onchidium inhabits crevices and depressions in rocks, always in the intertidal zone. As the tide ebbs, it comes out to feed, wandering about scraping algae. About an hour before high tide would submerge its home, it starts going back, always returning to its favourite crevice. This action shows that it has a homing instinct as well as an internal clock. Once submerged, it stays put without moving. Onchidiums in other countries like Australia live in holes in mangrove-flats.

Seemingly helpless, Onchidiums have a means of defence by having glands along the mantle edge giving off obnoxious secretions. When irritated, these repugnatorial glands are pointed at the intruder and shoot a jet some 15 cm away. This results in the retreat of inquisitive crabs and sea-stars.

41 The Bold and the Beautiful

Red darkness of the heart of roses,
Blue brilliant from dead starless skies,
And gold that lies behind the eyes,
Lustreless purple, hooded green,
The myriad hues that lie between …
Rupert Brooke

Best known among the snails without shells are the sea-slugs or nudibranchs. Unlike the lopsided snails, their body is bilaterally symmetrical. Named because of their resemblance to the land slugs, they are only remotely related to the latter, which, along with the land snails breathe air by the modified lining of their mantle cavity acting as a lung. And, unlike the drab, hideous, slimy land slugs, nudibranchs (meaning "naked gills") are brightly and even garishly coloured, rivalling in the beauty of their hues the prettiest butterflies and birds.

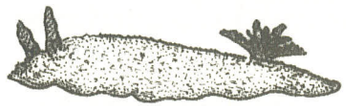


Fig.326 Side view of a sea-slug showing feathery "gills"

Unfortunately, the gorgeous colours disappear when the animals die and are preserved, so that they should be photographed in colour before preservation. This has also proved the bane of museum curators but the problem was ingeniously solved by two glass-blowers that were also keen naturalists. In the 1850s, Leopold Blaschka of Dresden and, later, his son Rudolf travelled to various places sketching marine invertebrates and then making glass models to be displayed in museums all over the world. This hobby was continued by Herman Mueller for the American Museum of Natural History, which has these glass reproductions of nudibranchs.

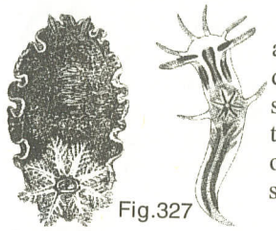


Fig.327 Top view of a typical dorid [left]; some dorids [right] are elongated like the aeolid nudibranchs, but are readily distinguished by the flower-like gills

Among several kinds of nudibranchs, the best known are dorids and aeolid sea-slugs. The dorids have a flattened disc-like or oval body; the upper portion, called notum, may be smooth or warty and has a projecting rim. The pair of stout tentacles bear ridges and are called rhinophores; they are organs of smell and can, in some dorids, be withdrawn into sheaths. Sea-slugs do not have internal gills. In dorids, the anus is situated in the midline towards the rear on the back and is encircled by a cluster of feathery so-called "gills". These are very sensitive to touch and can be withdrawn rapidly into a cavity whose aperture, when closed, looks like a pinhole.

Fig.328 A rhinophore

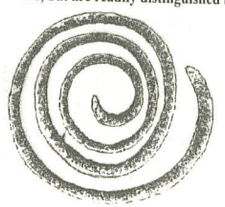
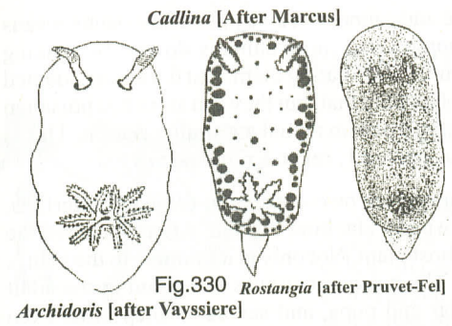


Fig.329 Egg-ribbon of a dorid

Sea-slugs are hermaphrodites, i.e., each animal has both the sexes. The eggs are laid counterclockwise in a spiral ribbon (when seen from above), this shape arising as the nudibranch slowly rotates on its foot while spawning. As the young develop inside the eggs, they can be seen to have a spirally coiled shell. The shell disappeared after birth.

This group of dorid sea-slugs comprises several genera, all ending with the suffix *-doris*, such as *Anisodoris, Archidoris, Chromodoris, Doris, Goniodoris, Glossodorsis, Lamellidoris, Onchidoris*, etc. These can be distinguished from the number of pinnae



Cadlina [After Marcus]
Archidoris [after Vayssiere]
Rostangia [after Pruvet-Fel]

Fig.330

(feathery portions) of the gills, nature of the back (smooth or warty), presence or absence of hooks or spines on the lips and penis. Thus, among the dorids in which the rhinophores and gills can be completely retracted within a pit and the penis is armed: *Glossodoris* (= *Chromodoris*) has a smooth, brightly coloured back, narrow projecting edge of notum (back), unipectinate gills and armed lips. *Doris* has a very warty back. *Cadlina* is smooth or slightly warty, with 5 to 12 bi or tri-pinnate gills. *Rostanga's* body is covered with papillae, has unipinnate gills and lips armed with hooks. *Archidoris* has a tuberculated back and smooth lips. *Jorunna* has a granular back, tripinnate gills, unarmed lips and male antrum (penis) bearing a stylet.

Among dorids in which there are no pits for the gills:*Onchidoris* (= *Lamellidoris*) has a warty back and unarmed penis. In *Goniodoris*, the mantle edge is very reduced, rhinophores not retractile and penis armed with hooks. *Okenia* (= *Idalia*) is similar but the mantle edge bears a row of tentacle-like projections. In *Notodoris*, the mantle edge around the back is absent or much reduced, and the rhinophores lack sheaths but can be withdrawn into a pit. *Polycera*, also with reduced mantle edge, has a frontal sail carrying some projections, similar projections along the gills, and a spiny penis. In the closely related *Triopha*, the edge of the back bears knotty projections. *Adalaria* has a tuberculated back and unarmed penis.

In addition to the well known dorid and aeolid nudibranchs, we also have dendronotacean and arminacean sea-slugs. The former have a sheath in which the rhinophore can be retracted. In the latter, such a sheath is wanting, a frontal sail is present, and cephalic tentacles are usually absent.

Arminacean nudibranchs are a heterogeneous group, as some of them resemble dorids while others are like aeolids.

Both these groups will be described in the next chapter.

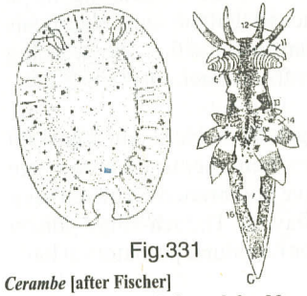


Fig.331
Cerambe [after Fischer]
Polycera [after Marcus]

It may be wondered how such inoffensive looking, brightly coloured sea-slugs can survive in the sea. After all, they cannot swim away and hide, do not have an armoured shell with spines, or fight back with claws. Nor does their colour match their surrounding. Dorid nudibranchs have evolved an unusual strategy for survival. They are highly selective about their diet, feeding on sponges, ectoprocts (Polyzoa) and sea-squirts (tunicates). But each kind will feed only on one particular food item. Thus *Rostangia* (which is red) feeds only on red sponges, the yellow *Archidoris* on the yellow sponge *Halichondria. Glossodoris*, *Peltodoris* and *Jorunna* are also sponge feeders, and coat the eaten pieces copiously with slime to protect the throat from the sponge's needle-like spicules. *Acanthodoris, Goniodoris, Onchidoris, Corambe, Polycera* and *Adalaria* feed on sea-squirts or moss-animals (Polyzoa), making a hole in the victim's body and sucking out the contents.

Now, animals which stay at one place and cannot run away must have some means of protecting themselves from enemies. Sponges and moss-animals do this by making poisons in their bodies which deters their enemies from eating them. But dorids are adapted so that they are not affected by these poisons. Not only that, but they can store this poison in their body, or modify the chemistry of their prey's poison to make a similar poison. This is the reason why a sea-slug will feed only on one, or closely related, prey species.

The sea-slug's chemical warfare weapons can be compared to those of butterflies. The female butterfly will lay its eggs only on a particular kind of plant. After it hatches, the caterpillar will suck the poisonous sap of the host plant. Not only is it immune to the plant's poison, but it stores that poison in its body. The poison continues to remain in the adult butterfly which emerges from the caterpillar and pupa, and serves to keep birds from attacking it because it is bitter in taste. The reason why butterflies and nudibranchs both are brightly coloured is to warn potential predators about their foul taste– an example of warning colouration. Man is only now learning about the chemical factory of the nudibranchs' prey and extracting potent medicinal drugs, such as the anti-cancer halichondrin (from a sponge) and bryostatin (from the polyzoan *Bugula*).

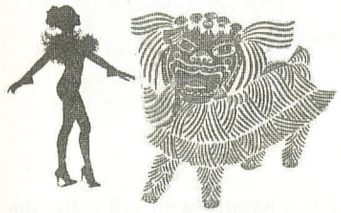
Like most snails, sea-slugs lay eggs from which free-swimming larvae (young) with coiled shells emerge, These swim in the sea for a month. In the vastness of the ocean, the larva has to find out the exact kind of sponge, moss-animal or sea-squirt which will serve as food for the adult that will ultimately emerge from it. It is like finding a needle in a haystack. Yet, aided by some kind of chemical cue, it searches for the ideal food-item and,once it finds it, settles down, gets rid of the shell and grows into a dorid.

While some sea-slugs modify the chemical poisons which they obtain from their prey in order to make them even more poisonous, others manufacture their own unique poisons. Such obnoxious poisons are secreted by what are called repugnatorial glands situated along the edge of the mantle in many dorids. Only 2% of the slime from a sea-slug introduced into a tank containing different kinds of fishes and crustaceans killed almost all of them within half to five hours; only a crab and another sea-slug survived.

The dorid nudibranch *Sclerodoris* has a sweet fragrance. It is not derived from its diet, but is manufactured by the sea-slug. It can be extracted from the body and actually smells like flowers. Other nudibranchs give out odours resembling those emanating from lemons, watermelons, or vanilla. It is believed that the same chemicals making the poison of a nudibranch are used to make these aromas and that, like warning colouration, they serve as warning smells to deter predators from attacking them.

Over a hundred years ago, the noted marine biologist W.A. Herdman theorised that gaudily coloured animals flaunt these colours to warn their enemies that they are foul to taste. To test this, he and a colleague had a meal of live nudibranchs. The sea-slug did not harm them; it turned out to be tasty, with an oyster flavour. The sea-slug's poison may not have been distasteful to them, but it definitely keeps its natural predators at bay.

42 Beauty and the Beast



Their glittering textures, like the filmy dew,
Dipped in the richest tincture of the skies,
Where light disports in ever-mingling dyes.

Unlike the drab, and ugly repulsive land-slugs, sea-slugs or nudibranchs are some of the most colourful marine molluscs without shells. While the Dorid group have a round, disc-like body, the aeolid and allied groups have an elongated, ploughshare-like body. There are two pairs of tentacles at the front end– a pair of simple cephalic tentacles, followed by the (usually) stouter rhinophores, these being the organs of smell. But the most peculiar characteristic of aeolids is the presence of tubular, nipple-shaped or branched structures called cerata, arranged along the back on either side, sometimes in clusters. These are used for breathing, but they also serve for defence.

There is a common saying, "You are what you eat." This does not imply that if we eat, say bananas, we shall soon have bananas growing all over our body. But something like this does happen in aeolid nudibranchs.

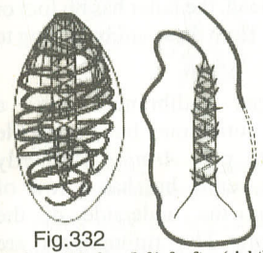


Fig.332
Stinging cell before (left) & after (right) discharge

Aeolids feed on coelenterates such as hydroids, alcyonarians (dead men's fingers), sea-anemones or corals. Now all these prey animals have an array of stinging cells (called nematocysts). A stinging cell is a capsule filled with a venomous fluid and containing a coiled hollow thread. When triggered by an enemy touching them, the thread is ejected out of the capsule and injects the fluid into the enemy, paralysing and killing it. The stinging cells of some hydroids are so virulent as to cause pain like the sting of a bee or red ant, and those of some jellyfishes can even kill a person within minutes.

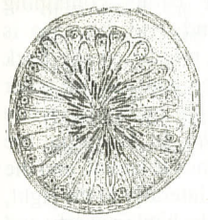


Fig.333
Stinging cells stored in cnidophore sac of an aeolid nudibranch

Yet the aeolid feeds on the coelenterates with impunity. It is not only immune to the stinging cells, but it manages to keep them undischarged. The stinging cells make their way uninjured and non-discharged through the stomach to bags called cnidosacs inside the cerata where they are stored for use. A fish attempting to eat an aeolid will only get a mouthful of painful stinging cells.

The aeolid and allied sea-slugs are identified by the nature of the rhinophores, the penis and the types of cerata.

Fig.334
***Tritonia* (after Pruvet-Fol)**

Fig.335 ***Marionia* (after Pruvet-Fol)**

The bushy-backed or dendronotacean nudibranchs have sheaths into which the rhinophores can be withdrawn. *Tritonia* and *Marionia* have a transverse fold on the end of the head, called a frontal sail. *Tritonia* feeds on alcyonarians, especially *Alcyonium. Hancockia* has a row of large serrated cerata, provided with cnidosacs, along each side of the back. *Dendronotus* has two rows of arborescent (tree-like) cerata. It feeds on hydroids.

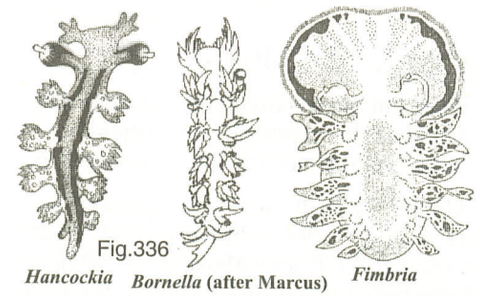


Fig.336
Hancockia *Bornella* (after Marcus) *Fimbria*

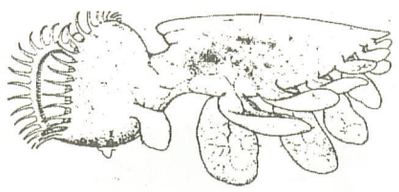


Fig.337 *Melibe* (after Agersborg)

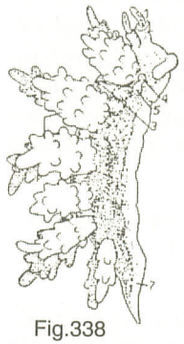


Fig.338
Doto (after Marcus & Marcus)

In *Bornella*, with branched cerata beset basally with gill tufts, the rhinophore sheaths are deeply slit. Both *Fimbria* (= *Tethys*) and *Melibe* have a greatly expanded head end, but while the former has gills at the base of the two rows of cerata, the latter lacks them. *Melibe* clings to seaweeds with its foot, and by swinging its expanded hood, traps planktonic animals like copepods, amphipods, isopods and small snails. The hood now closes and the excess water runs out, retaining the food. *Doto* has strongly tuberculated cerata, and feeds on hydroids. Both *Cephalopyge* and *Phylliroe* (also spelt *Phyllirhoe*) are translucent swimming forms with only a pair of rhinophores and without cerata, but while the former has a small foot, a three-branched midgut gland, and has a gland pit on the ventral surface of the head, the latter has no foot or gland pit and has a four-lobed midgut gland. Both these animals cling to siphonophores and prey on them.

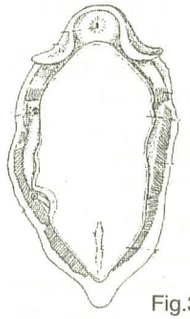
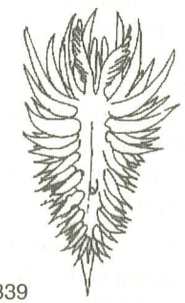


Fig.339
Armina (viewed from below) (after Hescheler)



Antiopella (after Marcus)

The arminacean nudibranchs have a frontal sail; they may sometimes have retractile rhinophores but not in pits. *Armina* (formerly *Pleurophyllidia*) lacks cerata but has a row of respiratory leaflets on the underside of the flattened back (notum). The rhinophores are retractile. *Janolus* and *Antiopella* have non-retractile rhinophores, have cerata containing branches of the midgut gland, and the anus is towards the rear and in the middle of the back (notum). *Armina* feeds on sea pansies and other Alcyonaria. *Janolus* feeds on hydroids, while *Antiopella* preys on *Corymorpha*. In *Madrella*, the rhinophores have papillae, the anus is lateral, and the cerata have branches of the midgut gland. *Dirona* has its anus shifted laterally to the right, and the midgut gland does not branch into the cerata. In *Goniaeolis*, the back is warty and without cerata, and its right side has two thin projecting lobes. *Hero* has a row of a few widely spaced, greatly branched cerata along each margin of the back; these and the rhinophores are invaded by branches of the midgut gland.

Fig.340 *Embletonia* (side view) (after Marcus)

Aeolid nudibranchs have cephalic tentacles and simple rhinophores without sheaths. Only *Embletonia* has a frontal sail. In the Pleuroprocta group of aeolid nudibranchs (example *Coryphella*, with numerous cerata), the anus is lateral.

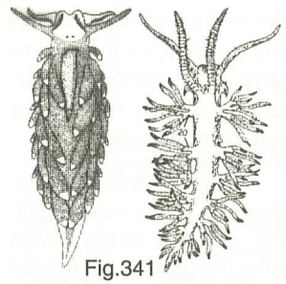


Fig.341
Catriona (after Marcus) *Flabellina* (after Vayssiere)

In the Acleioprocta group of aeolids, the anus has shifted dorsally between the main right and left branches of the midgut gland. *Cuthona* has the branches of the midgut gland simple and each bears a transverse row of cerata. *Catriona* is similar but the radula differs. *Embletonia* has no cephalic tentacles and has a single longitudinal row of cerata, without cnidosacs, along each side of the back. *Flabellina* has long cephalic tentacles and rhinophores; the cerata are slender processes borne on basal stalks and tipped with a cnidosac. *Fiona* is similar but has a lateral expansion of the numerous cerata. It feeds on siphonophores, such as *Porpita* and *Velella*. *Calma* has no intestine, anus or cnidosac; the numerous slender cerata are united into groups by basal stalks. It feeds on fish eggs, slitting open the egg membrane with its radula. *Pseudovermis* is very narrow and worm-like, without tentacles and rhinophores; the cerata are reduced to cnidosacs, each entered by a branch of the midgut gland.

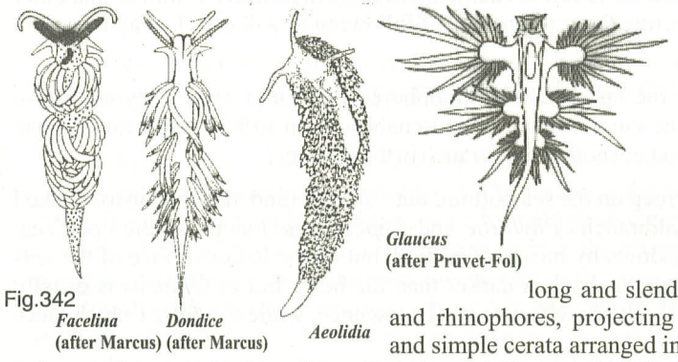


Fig.342
Facelina (after Marcus) *Dondice* (after Marcus) *Aeolidia*

Glaucus (after Pruvet-Fol)

In the Cleioprocta group of aeolids, the anus is located dorsally on the right side behind or among a group of cerata, and the radula has only one longitudinal row of teeth. *Facelina* is long and slender, has long tentacles and rhinophores, projecting anterior foot angles, and simple cerata arranged in transverse rows. The penis may be armed with spines. *Dondice* and *Cratena* (family Favorinidae) have an unarmed penis; at least the most anterior transverse rows of cerata are arranged in a horseshoe. In the Facelinidae and Favorinidae, the anus is located in the second right group of cerata. In the Aeolidiidae, it lies behind this or a more posterior group; in this family the penis is unarmed and the radular teeth are comblike. In *Aeolidia* (= *Aeolis*), the radular tooth is arch-shaped without a median notch. *Baeolidia* has flattened cerata, and the radular tooth has a deep median notch. *Aeolidina* is similar, but the anus is situated more posteriorly. In *Glaucus*, the head, tentacles and rhinophores are greatly reduced and the body extends laterally as three pairs of projections, each tipped with a cluster of cerata provided with cnidosacs.

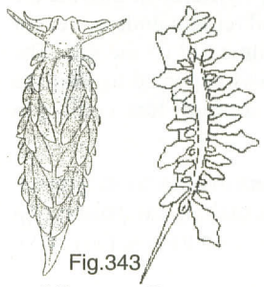


Fig.343
Stiliger (after Baba) *Hermaea* (after Marcus)

There are some forms such as *Stiliger* and *Hermaea* which have cerata and thus look like aeolid nudibranchs. But they belong to the same order as *Elysia*, viz. Ascoglossa (also called Sacoglossa), in which there is a sac inside which discarded teeth of the radula (tongue ribbon) accumulate.

The beautiful colours of nudibranchs may be made by the animal, acquired from food, or be caused physically. Thus the blue colour of the aeolid nudibranch *Fiona* is derived from its prey, the by-the-wind-sailor *Velella*, and fades when it cannot get its prey organism.

A tropical ascoglossan nudibranch which feeds on green filamentous algae separates out chloroplasts– the parts of the plant cell which carry out photosynthesis, and places them under its skin. The chloroplasts continue to carry out photosynthesis, manufacturing food which the nudibranch absorbs. The nudibranch can survive for short periods without eating anything, as long as it exposes itself to the sunlight.

The cerata of the aeolid nudibranch *Trichesia* have orange and blue bands, The orange colour is made by pigment cells in the skin, but the blue has a physical origin. Just as we see the colours of the rainbow in a patch of petrol or oil spilt on a wet road or in a soap bubble, the blue is an interference colour caused by seeing the dark midgut gland through the orange pigment of the animal.

If you notice a sea-slug crawling on the sea bottom, you will notice that it leaves a trail of mucus (slime). If another sea-slug comes across this trail, it will, quite often, follow it. After all, especially in the breeding season, it means another nudibranch to mate with. But, if the first nudibranch has been under some stress, e.g., having met a predator, it leaves behind some sort of chemical message in its mucous trail so that other nudibranchs coming across the trail, instead of following it, will crawl away from it in the opposite direction.

Here is where the nudibranch's rhinophores come into play. They can sense chemical cues from the environment, which enables them to test water quality, the presence of suitable food or another nudibranch in the vicinity.

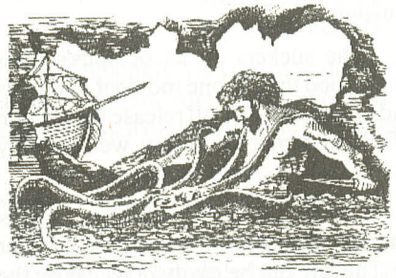
Most aeolids creep on the sea bottom, but *Glaucus* (and also the bushy-backed or dendronotacean nudibranchs *Phylliroe* and *Cephalopyge*) swim in the open sea. *Glaucus* swims upside down by means of its foot, but on the lower surface of the sea-surface. In most animals the back is darker than the belly, but as *Glaucus* is usually upside down, its back is silvery with a pearly iridescence, while the belly (which faces the sky) is dark blue.

When *Glaucus*, while drifting on the sea surface, comes across a blue dollar (*Porpita*) or by-the-wind-sailor (*Velella*), it attacks it, feeding on its tissues and passing the prey's non-discharged stinging cells into the three lateral lobes fringed with long conical processes. To add insult to injury, it lays its eggs on the skeleton of its prey.

The origin of the scientific name of *Glaucus*, given by Forster, is confusing. *Glaucus* means "silvery" in Greek. But it is also the name of a Greek god. In Greek mythology, Glaucos was a fisherman. He once kept his fish catch on a heap of seaweeds. The dead fishes came alive and started leaping back into the sea. The fisherman realised that the seaweed had some magical property that restored the fish's life, so he also ate the seaweed. From that day he could swim in the sea like a fish and remain underwater for hours. One day, he must have overdone it, for he failed to come out of the sea. The Greeks promptly elevated him to the rank of a god, and he was expected to visit the coasts and islands of Greece once every year, accompanied by sea monsters, coming in invisible and varied forms!

Other nudibranchs give out odours resembling those emanating from lemons, watermelons, or vanilla. It is believed that the same chemicals making the poison of a nudibranch are used to make these aromas and that, like warning colouration, they serve as warning smells to deter predators from attacking them.

43 Octopus—Odious or Ostracised?



He, 'mid the cruel horrors he intends,
Takes pleasure in a net by cunning hands
Contrived, which near his mansion he extends;
So well conceal'd beneath the crumbling sands
That whose uninstructed thither wends
Naught of the subtle mischief understands,
Whom with loud laughter to his seat hard by
He drags along, entangled in his snare;
Then, having suck'd their brains and life-blood dry,
Cast forth their bones upon the desert lair.

Aristo's *GIANT*

With the approach of winter, the seawater near our shore gets cooler. This signals the arrival of octopuses; first, the juveniles by mid-October, followed by the adults a few weeks later.

What the film "Jaws" has done to man's (mis)conception of sharks, Victor Hugo's novel, *Les Travailleuses de la Mer* (= The Toilers of the Sea) did for the octopus in 1866. It narrates a fight to the death, in a Channel Island sea-cave, between the hero and a "devil fish". (They very name that Hugo gives to the octopus sends shivers down one's spine.) But very few octopuses are in fact dangerous. Unlike the venomous Australian *Hapalochlaena maculosa*, whose bite has caused death within two hours, our octopuses are harmless. For nearly four decades, I have played with them, allowing them to glide up my arm and then peeling them off. Only once have I been bitten– just a smart nip which felt like a pinprick and drew a drop of blood.

Compared to the European octopus, whose body is the size of a football, with each arm 1 m long, our local octopuses are puny, with their body the size of one's fist and arms 45 cm long. The largest octopuses live in the Pacific Ocean. They have a body of 45 cm, arms some 485 cm, and weigh 45 kg. There are some 250 species of octopuses throughout the world, living from surf line down to 4·8 kilometres.

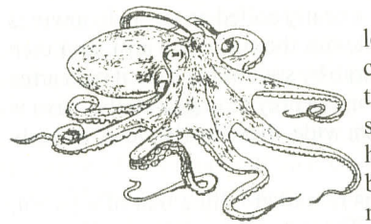


Fig.344 **Octopus at rest**

Surprisingly, octopuses are related to the lethargic snails and clams, but, along with their cousins the cuttlefish and squid, they are marine. The terms used to describe their body parts are sometimes a little confusing. What looks like the head, since it bears a pair of eyes, is actually the body, inside which are all the organs. Around the mouth are eight 'arms' bearing rows of round suckers. The arms are used for walking (why not call them feet?) and are connected at their base by a membranous web.

Tell me, O Octopus, I begs,
Is those things arms, or is they legs?
I marvel at the Octopus,
If I were thou, I'd call me Us.

Ogden Nash

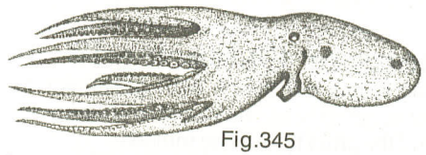


Fig.345

Octopus swimming head forward by Jet Propulsion

On the lower side of the body is the funnel or siphon, from which the octopus can expel water forcibly to swim backwards. It is Mother Nature's earliest version of jet propulsion.

The suckers on an octopus's arms can form a partial vacuum. Its nervous control is so good that, at one moment hundreds of suckers will attach themselves to an object, and at the next, all will release the suction and clamp down somewhere else. The suckers feel like hundreds of tiny, wet, clammy hands pulling at one's skin.

Like the tiger, the octopus is not a sociable creature. Except when mating, it lives by itself in a lair made by collecting a pile of stones, or in a hollow under a boulder which it has excavated by blowing out the sand. The lair can be easily detected by the debris of recent meals cluttered about its entrance.

But in the porch doth evermore abide
An hideous giant, awful to behold,
That stops the entrance with his spacious stride,
And with the terror of his countenance hold
Full many doth affray.

To catch an octopus in a tide pool, an easy method is to squirt a concentrated salt solution into the lair and wait patiently. If the octopus is inside, it will violently expel water through its funnel, sending a cloud of bubbles to the water surface. Soon the octopus will send out an exploratory arm. If it finds nothing suspicious, and as the salt starts to suffocate it, the octopus will emerge. (Tobacco, vinegar, slaked lime and copper sulphate have been used to flush out an octopus, but are highly polluting.)

When hungry, the octopus stalks its prey (crabs, lobsters, shellfish and sometimes smaller octopuses).

Alas, regardless of their doom
The little victims play!
No sense have they of ills to come,
Nor care beyond today.

Gray

If a crab passes by, the octopus will send out a neatly coiled arm which unwinds itself gently towards the crab. The victim is flicked with the tip of the arm, and then pulled to the octopus's mouth. Sometimes it hunts a crab by swimming over it with arms outstretched like an open umbrella and descending on the prey to engulf it. Its saliva is poisonous. The crab quickly succumbs; its claws open wide, then slowly close; its body quivers, and the crab is dead within 45 seconds.

The octopus's beak now comes into play. It is remarkably like that of a parrot, except that the lower beak is longer than the upper. The octopus opens the crab at the junction between its carapace and abdomen (the place from which the crab's soft body emerges when it moults). It pulls off the back, eats the body organs first, and then, one by one, pulls off the legs, cleans out the flesh with its arm tips and eats them, and then drops the empty shell outside its lair. (In captivity, it relishes boiled eggs.) While the saliva of Indian octopuses is not dangerous to humans, there is an Australian blue-ringed octopus (*Hapalochaena maculosa*) whose bite can kill a man in 90 minutes.

On his deep front majestic terror rode,
Which swelled in conscious pride the infernal god,
His mad'ning eye, whence streaming poison ran;
Giar'd like a comet threatening woe to man.
His mouth was like the whirlpool of the flood,
Dark, yawning, deep, and filled with grumous blood.

Surprisingly, its venom is the tetrodotoxin found in puffer fish, some trumpet shells and sea stars, some newts and frogs and a few gobies. But in these animals, it acts as a poison when ingested, while in this octopus it acts as a venom when injected.

An octopus is prone to autophagy, i.e., it often eats its own arms. This is supposedly done during times of stress and is frequently a preliminary to death.

In speed and variety of colour change, the octopus surpasses even the chameleon. It has a multitude of small pigment spots; brown, black, red, yellow, orange-red. At rest and undisturbed, its body is a purplish brown, often with irregular honeycomb patches. When frightened, it turns ashy grey. It is enthralling to see, even in a dead octopus, waves of dark and light tints passing over the body.

Even octopuses have enemies– sharks, moray eels, whales, porpoises, seals and sea birds like albatrosses. When approached by an enemy (even a scuba diver), the octopus remains still, relying on its camouflage. If the enemy persists in coming close, the octopus throws out a cloud of purplish 'ink' from its funnel, which diffuses in the water to form a smoke-screen. By the time the water has cleared sufficiently for the enemy to see, the octopus has slunk away. The ink seems to serve another purpose.The ink is composed of melanin pigments derived from the aminoacid tyrosine. When discharged as a dilute cloud, it spreads in the water to act as a smoke screen. But it can also be released simultaneously with a mucous binder, when it appears like a solid. It has the rough shape of an octopus, and acts as a decoy, confusing the enemy. The sense of smell of a moray eel which has swum into the ink cloud is lost for up to an hour. When a moray attacks, the octopus wraps its arms around the moray's head. To dislodge it, the moray forms a loop with its tail and slips its head backwards through this loop, thus forcing the octopus's arms to slide along the moray's slippery body and release their hold. In open water, a moray which has grabbed an octopus's arm will stretch its own body full length and then spin round and round with giddy rapidity until the arm is torn off the octopus's body with a violent wrench. The octopus might escape with the loss of an arm and be satisfied with the bargain; it can regenerate a new arm within six weeks.

As an escape artiste, the octopus is more than a match for Houdini. Except for its horny beak, its body is soft, allowing it to flatten its body and squeeze through unbelievably small openings. For example, an octopus the size of a tennis ball can easilysqueze through a 12-mm hole. So, for the local octopus, with its fist-sized body, squeezing through half-inch wire mesh is child's play. I once had an embarrassing experience of this proclivity to escape. After collecting octopuses at Madh Island, just outside Mumbai, I was travelling home by bus. Since fish and live animals are not allowed inside a bus, I had hidden the octopuses in an aluminium milk can. So that they should not suffocate, I had left the lid of the can slightly ajar, but not enough (or so I thought) for the octopuses to crawl out. Scarcely a kilometre later, there was a commotion at the rear of the bus. Some octopuses had squeezed out of the can, and were merrily crawling over the bus floor. A rather shamefaced me was evicted by the conductor!

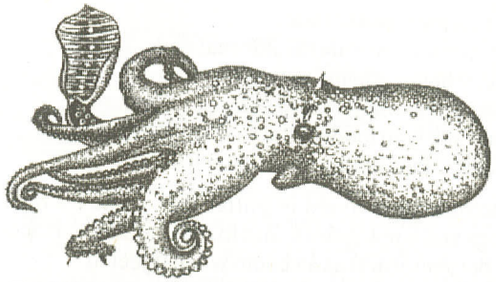


Fig.346 **Octopus, showing [3rd Rt.] hectocotylysed arm**

When a man decides on matrimony, he asks for the girl's hand in marriage. A male octopus with similar intentions, in contrast, offers his own–literally. The male's third right arm is modified to form what is known as a hectocotylus. While mating, this is inserted into the female's body and is used to plant sperm sacs into her oviduct. In some octopuses, the worm-like end of the arm breaks, and remains inside the female's body. In the argonaut, a distant cousin of the octopus, the hectocotylus breaks off from the body of the male, swims independently like a wriggling worm until it reaches a female, and fixes itself by means of its suckers onto the female's mantle cavity. The body of the female, which secretes a pearly white, fluted shell, may be 15 cm in size. The adult male is a tiny 6 mm. Its third left arm looks like a sac almost as big as its body. When the sac bursts, the hectocotylus unwinds to a gigantic 22 cm and breaks free to swim away.

The eggs of an octopus, which are as large as a grain of cooked rice, are laid at night, in 7 cm long clusters, each containing 25-50 opalescent white eggs. There are up to 30 such clusters, attached to stones or seaweed. Aquariums often provide cement pipes for octopuses to shelter in, and the egg clusters are stuck inside the pipes, hanging down like curtains.

Fishermen hunting the octopus make use of its fondness for secluded crannies. In the Palk Straits of South India, shells of the five-fingered conch are used to catch them. The apex and fingers of the shell are broken off, and 700 to 900 shells are strung along a long line. The line is set in two metres of water at the sea bottom and lifted each morning. The haul is usually 200 to 300 octopuses. In Japan and the Mediterranean Sea, earthenware pots are used.

Strange to say, you can hypnotise an octopus. Hold the octopus in one hand with the mouth upward, and with the arms and body hanging downwards. The trick lies in preventing the octopus's arms from touching yours, as this will break the hypnotic spell. If you can prevent such contact, and can hold the octopus in this manner long enough, its arms will hang limply, with no trace of movement. When an arm is lifted and let go, it will seem as lifeless as a length of rope. The octopus can even be passed from hand to hand. To awaken it, pinch hard.

44 Sleek and Savage

But yours is much of the cameleon hue,
To change the dye with every different view.

We consider snails to be slow, lethargic, dim-witted creatures, yet their close cousins– squids and cuttlefish are some of the fastest and most intelligent inhabitants of the sea.

These animals, together with the octopuses and nautiluses comprise the cephalopods (meaning head-footed); the foot refers to the arms that surround the mouth. While octopuses have eight arms, squids and cuttlefish (decapods, or ten feet) also have eight arms plus two longer ones called tentacles. All cephalopods are exclusively marine All these have two gills, while the pearly or chambered nautilus has four.

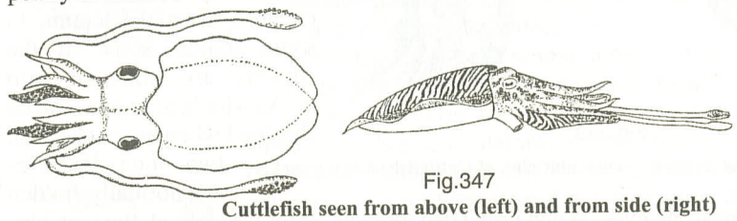


Fig.347
Cuttlefish seen from above (left) and from side (right)

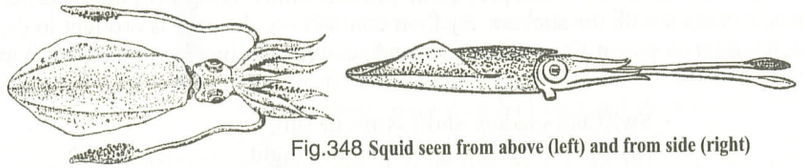


Fig.348 **Squid seen from above (left) and from side (right)**

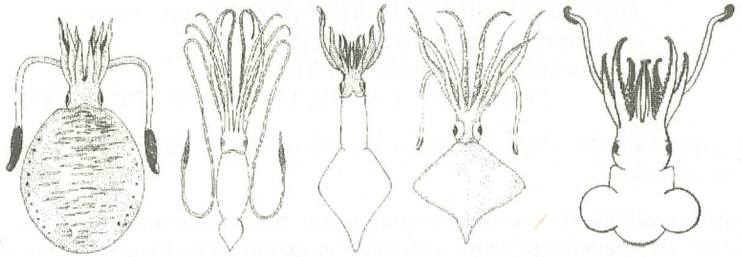


Fig.349 **Cuttlefish and squids come in all shapes and sizes**

Fig.350 **Position of Cuttlebone in a Cuttlefish**

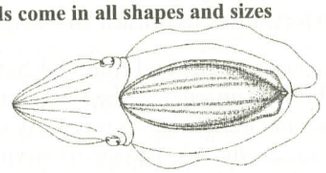


Fig.351 **Cuttlefish cut open to expose Cuttlebone**

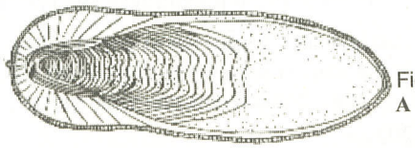


Fig.352
A cuttlebone

The body of squids is cigar-shaped, and has two fins along its sides or one at the rear end. Cuttlefish have broader, shield-shaped bodies and a frill of two thin narrow fins. Both have an internal "shell" or skeleton, not visible from the exterior. While the "pen" of squids is delicate and translucent, the "cuttlebone" of cuttlefish is white and hard but light in weight, having hollow chambers filled with gas; it is chalky due to the lime in it. The cuttlebone, also sometimes called sea-foam or sea-biscuit, is familiar to all who keep cage birds, being used as a source of calcium for avoiding brittle egg-shells. The cuttlebone is composed of minute multiple, parallel chambers containing gas (mainly nitrogen) in front and water in the hind portion. More liquid is pumped through the siphuncle into the chamber when the animal wants to dive; gas replaces the liquid for coming up.

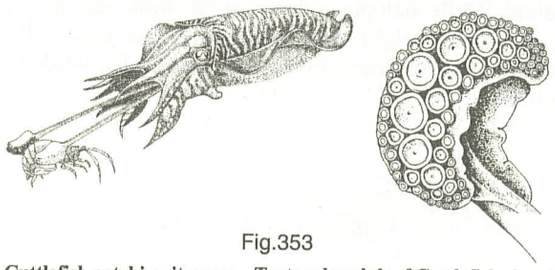


Fig.353

Cuttlefish catching its prey. Tentacular club of Cuttlefish showing suckers

The head bears eight similar, comparatively short arms having rows of suckers with horny rims. These can create a partial vacuum. In some squids, some of the suckers are changed into hooks which, as in cats, can be sheathed when not in use. The two long tentacles are normally hidden in two pockets near the eyes. When prey (fish, prawns, crabs) is sighted, the tentacles shoot out and grasp it with the suckers. By their contraction, the prey is brought to the arms which hold it. A parrot-like beak bites it and poisonous saliva is poured onto it to kill it.

Swift as a shadow, short as any dream;
Brief as the lightning in the collied night,
That in a spleen unfolds both heaven and earth,
And ere a man hath power to say 'Behold',
The jaws of darkness do devour it up.
Shakespeare *A MIDSUMMER NIGHT'S DREAM*

In turn, squids are eaten by seals, penguins, sperm whales. Sharks, whales and dolphins feed on cuttlefish.

Both squids and cuttlefish swim by jet propulsion. A muscular funnel, or siphon, below the body can shoot out jets of water with force, propelling it with speed. They can point the funnel forward or backward, so changing their direction of swimming.

Like octopuses, squids and cuttlefish have a gland which secretes a blackish fluid called "ink". This is squirted out when the animal is alarmed. It diffuses into the water, making it turbid, and the animal swims away to safety while the enemy is still groping for it. In some squids, the ink, instead of mixing rapidly with the water, forms a cigar-shaped dark cloud approximately the same length and diameter as the squid. The enemy attacks this dummy or phantom-shape while the squid escapes. Even newly born squids and cuttlefish can squirt ink.

Fig.354

Common Indian cuttlefish (*Sepia pharaonis*) showing normal colour pattern (top view) and colour variations according to mood (as seen from side)

Cephalopods are the masters of colour change. Tiny pigment cells called chromatophores in the skin usually of three colours out of black, brown, yellow, orange and red, can be expanded within two-thirds of a second in various combinations to give practically all the colours of a rainbow, except pure red and blue. About the size of a pinhead when expanded, the cell can contract to a pinpoint, leaving the animal a pale white. The pigment cells may be found even on organs inside the body, such as the walls of the ink-sac. In addition, there may be cells called iridophores, containing mirror-like reflecting plates The colour change depends on the animal's mood, but it continues for some time even after the animal is dead.

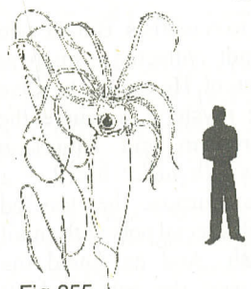


Fig.355

A giant squid (kraken) in comparison with a man

The camouflage is excellent. I have often slapped my palm hard on the water surface of a pool with squids. They all sank to the bottom and seemed to have vanished. But they were all there; only they had changed their colour to merge with the background and were lying motionless. Once I caught a small cuttlefish in a hand net. The net appeared empty except for a sag, from which I knew that it did contain something. The animal was lying in the net, motionless but with its body pearly white against the net cloth.

How does a cephalopod match its background so superbly? A cuttlefish has bright yellow pigment cells on the top of its skin, orange below this, and brownish red, brown or black still lower down. On a black, grey or white background, the red and yellow pigment cells contract and the extent of expansion of the black chromatophores determines the darkness or pallor of the animal. On a red or yellow background, the orange and yellow pigment cells expand fully, while the black ones contract. Cuttlefish do not have green chromatophores, yet by contracting orange while combining yellow and black with the expanded greenish iridophores, it can give a passable comparison. In a tank with black bottom on which I placed a white tile the cuttlefish had a square white blotch on its dark back, but the effect was spoilt by another small white dot at the rear and a white stripe on the head between the eyes. When alarmed, it turns pale white, but with two black spots on the back. Suddenly the whole body darkens to a purplish black by expanding all its chromatophores, the black dots thus disappearing.

Squids living in the depths also display luminescent spots of white, red or blue, Sometimes these light-producing organs are as complex as a camera, having a lens, reflector, colour filter and an iris diaphragm.

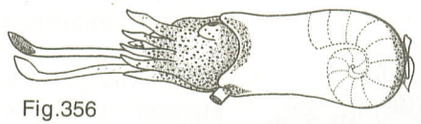


Fig.356
A Little Post horn (*Spirula*) showing position of internal shell

Related to squids is the Little Post-horn (*Spirula*). It is a deep-sea form, living between 300 and 800 metres below the sea surface. Unlike other squids which swim horizontally, *Spirula* positions itself vertically, with its arms hanging downwards. Between the small fins there is a circular disc with a small head-like organ in the center, which emits a steady yellowish-green light which glows for hours on end. Like many other planktonic animals, *Spirula*, makes vertical migrations every night through more than 500 metres.

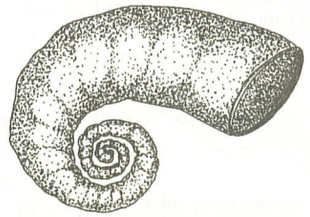


Fig.357 **Shell of *Spirula***

Inside the top end is a small shell, coiled in a flat spiral. It is divided into 25 to 37 chambers. The first one is filled with the animal's organs; the rest are filled with gas and serve to make the animal lighter. A delicate hose-like extension of the body, called a siphuncle, runs through the chambers. (In this manner *Spirula* is similar to the pearly nautilus.)

Until 1920, only 13 specimens of *Spirula* were known to scientists. But the two *Dana* expeditions, led by the Danish zoologist Johannes Schmidt, collected as many as 188 specimens. And Schmidt's main aim was completely different. He wanted to solve the mystery of where the European and American eels (*Anguilla*) breed. For this purpose he trawled with special nets with small mesh. And he found the answer; the eels bred 40 metres below in the Sargasso Sea. The nets that he used were ideal for catching the small *Spirula* as well.

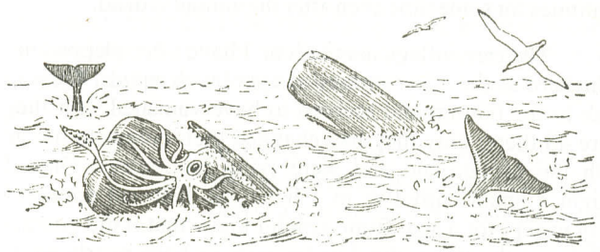


Fig.358 **A giant squid defending itself against a sperm whale**

Some squids grow extraordinarily large. Thus the giant squid or *kraken* (*Architeuthis*) of New Zealand are known to be more than 18 m. But this is their overall length, i.e., body plus tentacles. The body would be a little over 1·5 metres, These giant squids are the food of sperm whales, whose stomach often contains their undigested beaks, or even parts of the prey. R.J. Daniel found a squid with tentacles 6·3 m long in a whale's stomach. The largest sucker was 2·5 cm in diameter, but on some whales' heads there are scar-marks of suckers 25 cm in diameter.

While these scars suggest a giant squid 91 m in length, it is generally thought, instead, that the size of the scars can be attributed to the growth of the scar along with the growth of the whale.

There are several authentic accounts of attacks by cephalopods on boats and even small ships. One that happened near the Nicobar Is. appeared in 'The Times' of July 4, 1874 and is given here. "We had left Colombo in the steamer *Strathowen*, had rounded Galle, and were well in the bay, with our course laid for Madras, steaming over a calm and tranquil sea. About an hour before sunset on the 10th of May

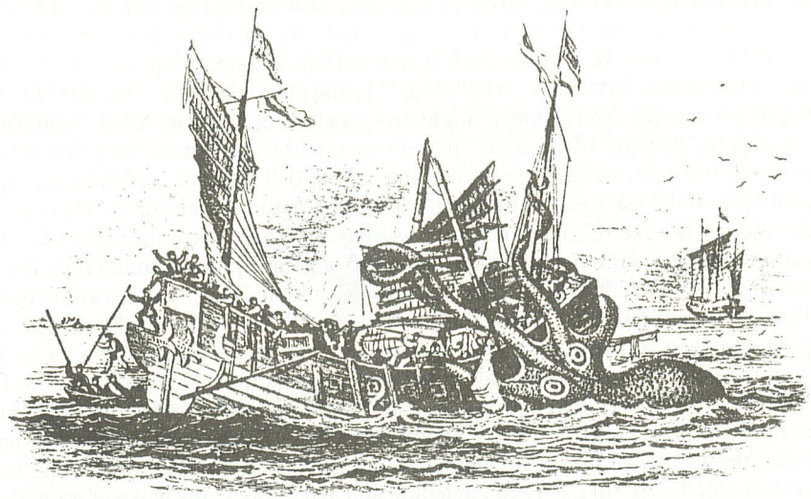


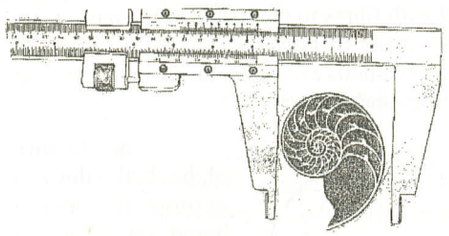
Fig.359 **Kraken or poupe colossal attacking a ship (as described by Denys de Montfort)**

we saw on our starboard beam and about two miles off a small schooner lying becalmed. There was nothing in her appearance or position to excite remark, but as we came up with her I lazily examined her with my binocular, and then noticed between us, but nearer her, a long, low, swelling lying on the sea, which from its colour and shape I took to be a bank of seaweed. As I watched, the mass, hitherto at rest on the quiet sea, was set in motion. It struck the schooner, which visibly reeled, and then righted. Immediately afterwards the masts swayed sideways, and with my glass I could clearly discern the enormous mass and the hull of the schooner coalescing I can think of no other term. Judging from their exclamations, the other gazers must have witnessed the same appearance. Almost immediately after the collision and coalescence the schooner's masts swayed towards us, lower and lower; the vessel was on her beam-ends, lay there a few seconds, and disappeared, the masts righting as she sank, and the mast exhibiting a reversed ensign struggling towards its peak. A cry of horror rose from the lookers-on, and, as if by instinct, our ship's head was at once turned towards the scene, which was now marked by the forms of those battling for life– the sole survivors of the pretty little schooner which only 20 minutes before floated bravely on the smooth sea. As soon as the poor fellows were able to tell their story they astounded us with the assertion that their vessel had been submerged by a gigantic cuttlefish or Calgary, the animal, which in a smaller form, attracts so much attention in the Brighton Aquarium as the octopus. Each narrator had his version of the story, but in the main all the narratives tallied so remarkably as to leave no doubt of the fact. As soon as I was at leisure, I prevailed on the skipper to give me his written account of the disaster, and I have now much pleasure in sending you a copy of his narrative:

"I was lately the skipper of the *Pearl* schooner, 150 tons, as tight a little craft as ever sailed the seas, with a crew of six men. We were bound from Mauritius for Rangoon in ballast to return with paddy, and had put in at Galle for water. Three days out we fell becalmed in the bay (lat. 8°50' N., long. 84°5' E). On the 10th of May, about 5 p.m.– eight bells I know had gone– we sighted a two-masted screw on our port quarter, about five or six miles off; very soon after, as we lay motionless, a great mass rose slowly out of the

sea about half a mile off on our larboard side, and remained spread out, as it were, and stationary; it looked like the back of a huge whale, but it sloped less, and was of a brownish colour; even at that distance it seemed much longer than our craft, and it seemed to be basking in the sun. 'What's that?" I sang out to the mate. "Blest if I knows; barring its size, colour, and shape, it might be a whale," replied Tom Scott; "and it ain't the sea sarpent," said one of the crew, "for he's too round for that ere Critter. "I went into the cabin for my rifle, and as 1 was preparing to fire, Bill Darling, a Newfoundlander, came on deck, and, looking at the monster, exclaimed, putting up his hand, "Have a care, master; that ere is a squid, and will capsize us if you hurt him." Smiling at the idea, I let fly and hit him, and with that he shook; there was a great ripple all round him, and he began to move. "Out with all your axes, and knives", shouted Bill, "and cut at any part of him that comes aboard; look alive, and Lord help us." Not aware of the danger, and never having seen or heard of such a monster, I gave no orders, and it was no use touching the helm or ropes to get out of the way. By this time, three of the crew, Bill included, had found axes, and one a rusty cutlass, and all were looking over the ship's side at the advancing monster. We could now see a huge oblong mass moving by jerks just under the surface of the water, and an enormous train following; the oblong body was at least half the size of our vessel in length and just as thick; the wake or train might have been 100 feet long. In the time that I have taken to write this the brute struck us, and the ship quivered under the thud; in another moment, monstrous arms like trees seized the vessel and she heeled over; in another second the monster was aboard, squeezed in between the two masts, Bill screaming "Slash for your lives", but all our slashing was of no avail, for the brute, holding on by his arms, slipped his vast body overboard, and pulled the vessel down with him on her beam-ends; we were thrown into the water at once, and just as I went over I caught sight of one of the crew, either Bill or Tom Fielding, squashed up between the masts and one of those awful arms; for a few seconds our ship lay on her beam-ends, then filled and went down; another of the crew must have been sucked down, for you only picked up five; the rest you know. I can't tell you who ran up the ensign. James Floyd, late master, schooner *Pearl*.

45 The Mathematical Prodigy



You can work it out by Fractions or by simple Rule of Three,
But the way of Tweedle-dum is not the way of Tweedle-dee.
You can twist it, you can turn it, you can plait it till you drop
But the way of Pilly-Winky's NOT the way of Winkle-Pop!

Rudyard Kipling *Servants of the Queen*

Some three and a half centuries ago Galileo Galilee declared that the book of nature was written in the language of mathematics. Like oil and water, biology and mathematics normally do not mix. But there are some animals which have mastered geometry; one such is the pearly, or chambered, nautilus. Found in the open seas of the western Pacific Ocean from the Philippines to Fiji, they live near the bottom at depths down to 600 metres. Millions of years ago, they were numerous; nearly 3,500 different kinds have been dug up as fossils– some with shells as large as 4·5 metres across. Today, only six species occur. They can be termed "living fossils"– representatives of an order which goes back to the beginning of animal life on earth.

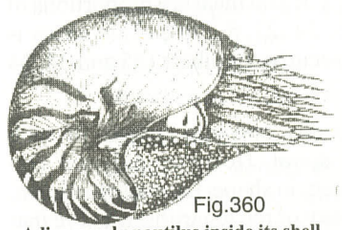


Fig.360
A live pearly nautilus inside its shell

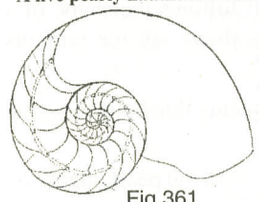


Fig.361
Section of pearly nautilus shell

Cousins of squids, cuttlefish and octopuses, pearly nautiluses differ in having four gills (instead of two in the others) and in lacking an ink-sac (the organ which produces "ink" used as a smoke screen). The animal lives inside a limy white shell with reddish brown flame stripes. The inner side of the shell has a beautiful pearly sheen, being lined with mother-of-pearl. The shell is peculiar in having many chambers (25 to 38), separated by partitions, each with a small hole communicating with the next chamber. The animal lives only in the last (and largest) chamber, the rest being filled with gas. The newly born nautilus, half the size of a pea, already has four chambers. A new chamber is made every 2-3 weeks. The animal can rise and sink in the water by increasing or reducing the amount of gas in the chambers. It swims by throwing out jets of water from its funnel. When alarmed, it can withdraw into its shell and cover the opening by a leathery hood. The shells are often found on the Andaman and Lakshadweep coasts after a storm.

As with its cousins, the pearly nautilus also has arms, but these do not have suckers, and they are numerous. A female may have as many as 94 arms, while the male may have 60. The arms are in two groups, and the outer group always has 38.

Octopuses, squids and cuttlefish have the best eyes among backboneless animals, rivalling those in birds and mammals, but the eyes in a pearly nautilus are primitive. The eye has no lens and the light passes through a tiny opening of the eye. The eyes thus function on the principle of a pin-hole camera. Other primitive characters are an absence of salivary glands and pigment cells in the skin. So a pearly nautilus cannot

change its colours in the remarkable manner that octopuses and cuttlefish do. It lays eggs singly (not in clusters); they are quite large– about 45 mm long.

In New Britain and the southern Philippines, pearly nautiluses are caught in basket traps. Small, soft skinned fish are tied with fibres to the inside of the basket and serve as bait. The traps are lowered by ropes made of rattan (cane) down to 55-130 metres at night and hauled up in the morning. The shells are made into lamps, cups and saucers, spoons, ear-rings, bangles, studs, buttons and fish lures.

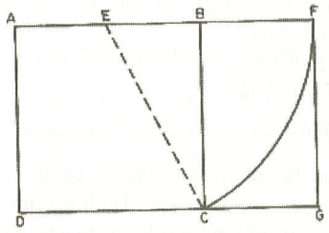


Fig.362 How to construct a golden rectangle

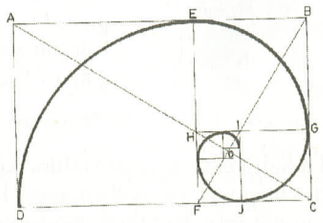


Fig.363 Producing a logarithmic spiral

The beauty of the shell is due to a geometric design based on what are known to mathematicians as the golden rectangle and the equiangular or logarithmic spiral. A golden rectangle has a proportion which is aesthetically more pleasing than a narrower or broader one. To make a golden rectangle **(fig.362)**, draw a square ABCD and project lines further along AB and DC. Bisect AB, and with E as centre, draw an arc of a circle with radius EC until it cuts the extension of the line AB (at F). Drawing parallel lines, complete the rectangle BFGC. BFGC and AFGD are golden rectangles. The rectangle BFGC can, in turn, be cut into a smaller rectangle **(fig.363)** and a square and so on indefinitely (ABCD, EBCF, HGCF, HIJF etc.). If you measure proportions of these golden rectangles, you will find them as 89, 55, 34, 21, 8 ... etc. This series is known as a Fibonacci series, and each pair of two consecutive numbers (55 and 34, 34 and 21, etc.) are called Fibonacci numbers.

By drawing arcs of circles joining the diagonally opposite corners of each square of a golden rectangle, we get a logarithmic spiral. However different two segments of the curve may be in size, they are not different in shape. (A mathematician, Jakob Bernoulli, was so enthralled by the sensuous beauty of the logarithmic curve that he had it engraved on his tombstone!) A pearly nautilus shell follows the shape of a logarithmic spiral; it can grow outward indefinitely, but its shape always remains unchanged.

As Francis Bacon so aptly said, "There is no excellent beauty that hath not some strangeness in the proportion."

Beauty of form and mathematics may have been combined in the pearly nautilus, but these are often two different entities when it comes to real life, as happened to my friend. Aged 17 and a student of fine art, he had to sketch live models, sometimes posing semi-nude, in his art classes. As the women were often middle-aged plantain sellers outside the art school who were offered a small sum to sit still and pose for hours, their figures were not what one sees with fashion models on the ramp.

One day he came across a book titled "Fun with figures". The price was reasonable so, after casting a furtive look around that none of his friends were around, he purchased the book and quickly put it in his bag, his mouth watering at the prospect of eyeing well-endowed beautiful models in the privacy of his home. Imagine his horror when he opened the book after reaching home. It was full of arithmetic problems and quizzes dealing with numbers! The book's title was appropriate, but, with his one-track

mind, he had not realised that "figures" do not always mean beautiful women!

The pearly nautilus has the proud privilege of having many poems written about it. Two are given here.

Oliver Wendell Holmes *The Chambered Nautilus*

This is the ship of pearl, which poets feign,
Sails the unshadowed main
The venturous bark that flings
On the sweet summer wind its purpled wings
In gulf enchanted, where the Siren sings,
And coral reefs lie bare;
Where the cold sea-maids rise to sun their streaming hair.

Its webs of living gauze no more unfurl;
Wrecked is the ship of pearl!
And every chambered cell,
Where its dim dreaming life was wont to dwell,
As the frail tenant shaped his growing shell,
Before thee lies revealed
Its irised ceiling rent, its sunless crypt unsealed!

Year after year beheld the silent toil
That spread her lustrous coil; Still, as the spiral grew,
He left the past year's dwelling for the new,
Stole with soft step its shining archway through,
Built up its idle door,
Stretched in his last-found home, and knew the old no more.

Thanks for the heavenly message brought by three,
Child of the wondering sea,
Cast from her lap, forlorn!
From thy dead lips a clearer note is born
Than ever Triton blew from wreathed horn!
While on my ear it rings.
Through the deep caves of thought I hear a voice that sings:-

Build thee more stately mansions, O my soul,
As the swift seasons roll!
Leave thy low-vaulted past!
Let each new temple, nobler than the last,
Shut three from heaven with a dome more vast,
Till thou at length are free
Leaving thine outgrown shell by life's unresting sea!

G.F. Richardson *The Nautilus and the Ammonite*

The Nautilus and the Ammonite
Were launched in storm and strife;
Each sent to float in its tiny boat
On the wide, wild sea of life,

And each could swim on the ocean's brim,
And anon its sails could furl,
And sink to sleep in the great sea deep
In a palace of pearl.

And theirs was a bliss more fair than this,
That we feel in our colder time;
For they were rife in a tropic life
In a brighter, happier clime.

They swam mid isles whose summer smiles,
No wintry winds annoy;
Whose groves were palm, whose air was balm,
Whose life was only joy.

They roam'd all day through creek and bay,
And travers'd the ocean deep;
And at night they sank on a coral bank,
In its fairy bowers to sleep.
And the monsters vast of ages past,
They beheld in their ocean caves;
And saw them ride in their power and pride,
And sink in their billowing graves.

Thus hand in hand, from strand to strand
They sail'd in mirth and glee;
Those fairy shells, with their crystal cells,
Twin creatures of the sea.

But they came at last to a sea long past,
And as they reach'd its shore;
The Almighty's breath spake out in death,
And the Ammonite liv'd no more.

And the Nautilus now in its shelly prow,
As o'er the deep it strays;
Still seems to seek, in bay and creek,
Its companion of other days.

And thus do we, in life's stormy sea,
As we roam from shore to shore;
While tempest-lost, seek the loved the lost,
But find them on earth no more!

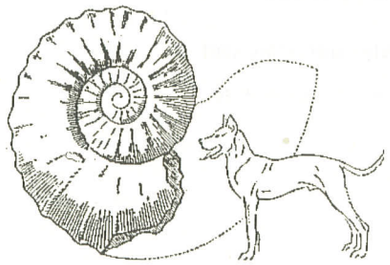


Fig.364 **A fossil ammonite, with a Great Dane for comparison of size**

The ammonites, or serpent-stones, are fossil cousins of the pearly nautilus, so named because their shell looks like the emblem of the ram-headed god Ammon of ancient Egypt. They ranged in size from the 12 mm *Cymbites* to 2¾ metre *Pachydiscus*. They reached their heyday 200 million years ago, and died out 80 million years ago.

This largest of ammonites, called *Parapuzosia seppenradensis* (2.6 m in diameter) lived some 78 million years ago and was found near Munster in Germany. Another ammonite from the same age, and 1.7 m in diameter,was found n Texas. The 1.5 m *Lytoceras* from New Zealand is 140 million years old.

Gems marketed under the trade names Calcentine and Korite are made of especially well preserved fossil ammonite shells extracted from deposits in southern Alberta, Canada. They are cut in an oval shape like opal, but the mosaic of crimson, green, blue, violet and gold is more brilliant than in opal.

There are six species of argonauts. They are *Argonauta argo*, *A. cornutus*, *A. bottgeri*, *A. hians*, *A. nodosa* and *A. nouryi*.

The female argonaut begins to make its tissue-thin shell shortly after hatching; the male does not secrete a shell. Just as in gastropod molluscs, the early whorls of her shell are made when the animals is small, therefore it would be impossible for a large female to start again and make an entirely new one, in case she loses her shell. The shell provides buoyancy for the animal due to gas trapped in the smallest whorls. So, if the argonaut were to leave its shell, she would immediately sink and die.

Two of the argonaut's arms are modified into membranous webs. It is these webs that form her shell. These webbed arms clasp the shell, the two webs stretching one over each side. As the argonaut grows larger, the edges of the web secrete calcium carbonate to enlarge the shell along the open margin.

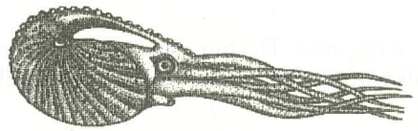


Fig.365 **A female paper nautilus**

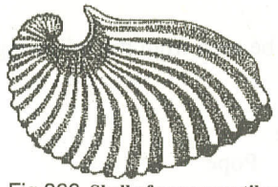


Fig.366 **Shell of paper nautilus**

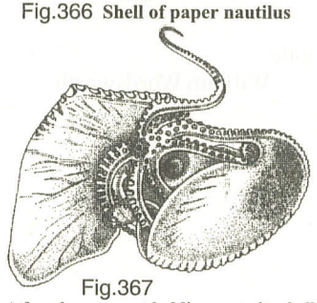


Fig.367
A female argonaut holding on to its shell

The paper nautilus, or argonaut (*Argonauta argo*), is not related to the pearly nautilus, but is a cousin of octopuses. The name is derived from Greek mythology in which heroic sailors sailed with Jason in the ship 'Argo' in search of the golden fleece. Its other name comes from the fragile, papery, pearly white, fluted shell, between the two flaps of which the female lives. The female grows to about 30 cm and is found in all the warm seas of the world near the sea surface, but also occasionally down to 900 metres. Of the eight arms with suckers, two have their tips expanded into broad oval flaps, which secrete the shell. These two arms sweep back along each side of the shell and hold it to her body. The two halves of the shell are joined at one margin to form a keel, decorated by a double row of brown knobs. If removed from the shell, the animal cannot make another one and dies.

Paper nautiluses swim by shooting jets of water out of the funnel, but occasionally ride piggyback on jellyfish. Six species occur in the world.

The search for the male argonaut is a fascinating tale. Till the 19th century, no one had seen one. In 1827, Delle Chiaje found a small worm-like body stuck to a female argonaut, and thought it to be a parasitic worm. Later, Georges Cuvier examined one, about 12 mm long, and noticed that it had 104 suckers, so he named it “Hectocotylus” (the arm of a

hundred suckers). Albert Kolliker, in 1845-46, noted that the suckers on the "parasitic worm" resembled those of female argonauts, that the "worm" contained, inside a cavity, sperms characteristic of octopuses, and also that it had pigment cells of the type found in octopuses. He also found that when it was separated from the female argonaut, it lived for several hours, wriggling about in the water.

Surely this was the male argonaut! In his eagerness to publish, he "invented" evidence. He went on to make fictitious illustrations of the gills, digestive tract and circulatory system. He jumped to this conclusion without realising that this animal had no heart, did not breathe and did not eat. It was Heinrich Muller who corrected Kolliker's error when, in 1853, he examined some tiny males hardly 6 mm long and without shells. He found that there was a sac among the arms which, when opened, had a hectocotylus inside. He realised that the third left arm, or hectocotylus, is enclosed in a sac. The arm consists of a sperm reservoir at the base, 50 to 100 tiny suckers on the middle, and a long thread-like male organ at the tip. Due to the vigorous wriggling of the hectocotylus, the sac enclosing it bursts. The arm comes out, unwinds to its 12 mm length– ten times longer than the male argonaut itself. It swims in the sea till it reaches a female, and fixes itself to her mantle cavity. No wonder that Delle Chiaje and Cuvier thought it to be a parasitic worm. And Kolliker was so embarrassed that he bought all copies of his earlier, erroneous publication and destroyed them!

Now we know that the male paper nautilus is a puny dwarf, one-twentieth the size of the female. The size difference is like that between a pea and a football, or a mouse and a lion.

The paper nautilius's shell is actually an egg-nest. The tiny (0.8 mm) eggs are laid in bunches attached to a thin stalk. The stalks, in turn, are stuck to the knobbed keel of the shell.

Dolphin fish (*not* dolphins, which are mammals), sailfish and broadbill swordfish prey on argonauts.

Poets have not forgotten the paper nautilus, as can be seen from the following selections:-

Learn of the little Nautilus to sail,
Spread the thin oar and catch the driving gale

Pope

Spread, tiny Nautilus, the living sail,
Dive at thy choice, or catch the freshening gale.

William Wordsworth

Who was the first sailor? Tell me who can;
Old father Neptune! no, you're wrong,
There was another ere Neptune began;
Who was he? Tell me. Tightly and strong,
Over the waters he went he went,
Over the waters he went.
Who was first sailor? Tell me who can;
Old father Noah! no, you're wrong,
There was another ere Noah began,
Who was he? Tell me, Tightly and strong,
Over the waters he went--- he went,

Over the waters he went.

Who was the first sailor? Tell me who can;
Old father Jason! no, you're wrong,
There was another ere Jason began,
Don't be a blockhead, boy! Tightly and strong,
Over the waters he went.

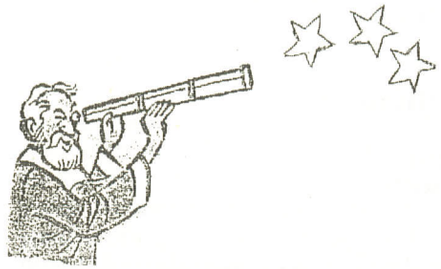
Ha! 'tis nought but the poor little Nautilus
Sailing away in his pearly shell;
He has no need of a compass like us,
Foul or fair weather he manages well!
Over the water he goes he goes,
Over the water he goes.

Mary Howitt

The tender Nautilus who steers his prow,
The sea-borne sailor of his shell canoe,
The ocean Mab, the fairy of the sea,
Seems far less fragile, and, alas! more free.
Themselves but shadows of a shadow world.

Tennyson

46 Stars In The Sea



Twinkle, twinkle, small sea-star,
I know full well what you are;
A case-study in geometry
With perfect five-fold symmetry.
(With apologies to Jane Taylor)

If you ask a person who knows almost nothing of marine life to draw a starfish, chances are that he will do a good job of it– a perfect five-pointed star, with the central disc merging into five tapering arms with broad bases. Scientists frown on the word "starfish", as it conveys a meaning that it is related to fishes, so let us call them "sea-stars" instead.

Sea-stars, along with their cousins, have two peculiarities. They are never found in fresh water, but are exclusively marine. Secondly, they are not bilaterally symmetrical. You can cut a human being, a snake, a frog, or even a worm into two equal left and right halves. But sea-stars show a radial symmetry, i.e., the organs of the body are arranged like the spokes of a wheel round a central axis and they are five or in multiples of five.

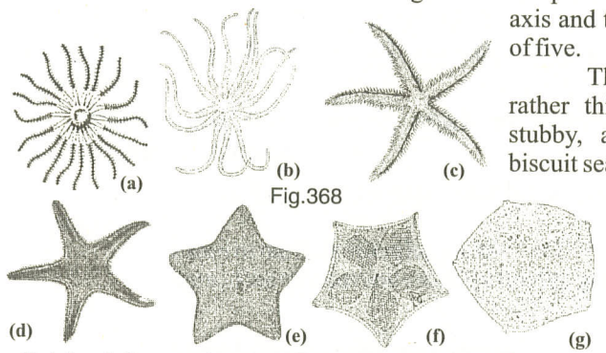


Fig.368

Variations in the arms of sea-stars : From left a) *Odinia* (After Perrier) b) *Freyella* (After Hyman) c) *Luidia* (After Fell), d) *Pseudarchaster,* e) *Oreaster,* f) *Pentagonaster* (After Sladen), g) *Culcita* (After Gregory)

The arms of a sea-star may be rather thin and long or thick and stubby, and sometimes as in the biscuit sea-star, or even absent, only a five-sided disc being present. And while a typical sea-star has five arms, there may be many more– in some kinds as many as 20 or even 45 to 50. On the upper surface is a prominent round, red or orange, grooved pore-plate or madreporite, situated off-centre between two arms, and an anus. In many-armed sea-stars, there will be up to five pore-plates (rarely, as many as 16). The body is rarely smooth; there are warts, knobs, tubercles or blunt-ended spines. The roughness is due to limy plates or ossicles embedded in the skin.

Many sea-stars are prettily coloured– red, orange, blue, green, grey or brown, sometimes with mottled and banded patterns of contrasting colours. Their size varies from a few centimetres to 60 cm (from arm tip to arm tip).

If you turn a sea-star over onto its back, you will find in the centre its mouth. From this, along each arm runs a furrow, called ambulacral groove, lined on each side by hundreds of tube-feet in two or four rows. The tube-feet are tiny, transparent, hollow and finger-like, and usually end in a flat sucker.

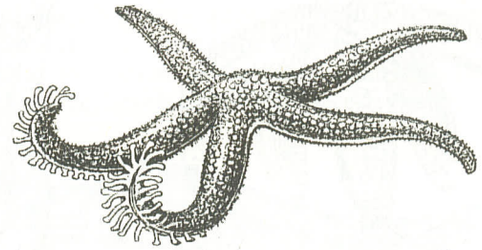


Fig.369 **A sea-star with the tips of two of its arms upturned to show tube feet**

A sea-star has the most ingenious hydraulic system devised by nature. From the pore-plate on the top of the body descends a hard limy tube called the stone canal. This empties into a ring canal, so called because it forms a ring around the mouth. From this runs a radial canal in each arm. A sea-star crawls slowly on the sea bottom, at about 15 cm per minute, by means of its tube-feet. These are hollow, and when sea water from the radial canals is pumped in, they distend, move outward and press against the sea floor. Now water is pumped out of the tube-feet, so that a vacuum is formed and the tips of the tube-feet, acting like suckers, stick to the sea bottom. Then, by contracting the muscles of the tube-feet and shortening them, the sea-star draws itself forward by means of the firmly anchored feet. Pumping water into them releases the tube-feet from the sea bottom, water is pumped into another group of tube-feet which get attached to the sea bottom farther on. A man-made hydraulic system would require a complicated control system housed in a big control room, but the sea-star manages all this by a small brain, and hundreds of tube-feet, controlled by nerves, operate in regular succession, which adhere and let go one after another in a superbly synchronised manner. Some sea-stars, by flinging sand outward with the help of their tube-feet, can bury themselves in the sand in a minute.

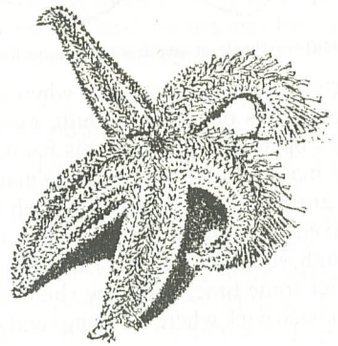


Fig.370 **An overturned sea-star somersaulting (After Romanes & Ewart)**

An upside down sea-star can right itself in many ways. Usually it bends two or more of its arms until the arm-tips touch the sea floor. These then begin walking, so to speak, under the animal, bringing more and more tube-feet in contact with the ground, and finally it somersaults. Or the sea-star rises on the tips of all its arms to assume what is called the "tulip" position, and then falls over. In the inverted tulip manoeuvre the sea-star brings all its arms vertically up and rolls over.

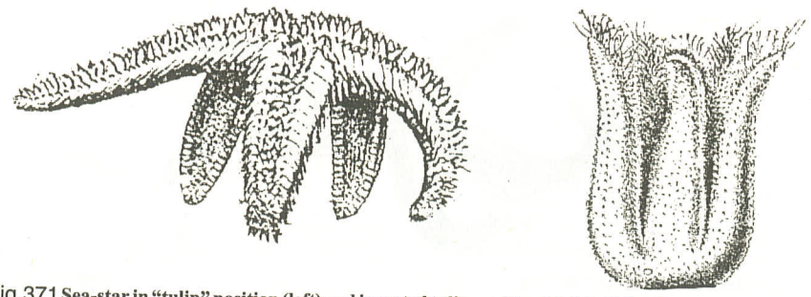


Fig.371 **Sea-star in "tulip" position (left) and inverted tulip position (right). (After Romanes & Ewart)**

The sea-star moves slowly and cannot chase fast moving prey. Its favourite food is shellfish, though if a fish is foolish enough to stray in its path and get caught by the tube-feet, well– the sea-star does not mind eating it. Now, anyone who has tried to get a knife into a live clam or oyster knows how frustrating it is. So how does a sea-star open one? It grasps the clam with its tube-feet, brings it towards the mouth and humps itself over the clam. While the tips of the arms maintain a foothold on the sea floor, it turns the clam until the edges of its shell touch the sea-star's mouth. The firmly attached suckers of the tube-feet steadily pull the two valves of the clam's shell in opposite directions. A clam's muscles can be ruptured in several hours under a continuous pull of 1,000 to 2,000 grams, whereas a sea-star can exert a pull of 1,300 grams before the tube-feet tear. So what the sea-star lacks in muscular strength, it makes up for in tenacity of purpose. A pull of over 900 grams suffices to open the clam in half an hour.

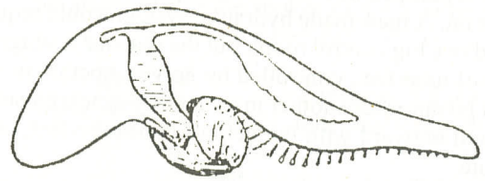


Fig.372 **Sea-star (in section) everting its stomach out of its mouth to feed on the opened clam. (After Hirsch)**

Imagine yourself sitting in a restaurant when someone occupies the chair next to you, takes his false dentures out of his mouth, mashes up the food on his plate by clamping the dentures open and shut with his hands, and pops the dentures into his mouth along with the mashed food. It's bad table manners, to say the least. Many sea-stars have an equally grotesque way of handling their food. After the clam or oyster has finally tired and relaxed its shell valves just a few millimetres, the sea-star pops its stomach out of its mouth, squeezes it into the shellfish and pours out its digestive juices into the shellfish. After some time, when the shellfish's tissues have been thoroughly digested, it puts its stomach back where it belongs and slurps the digested food in.

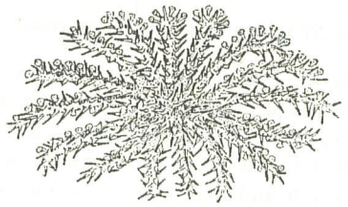


Fig.373 **Crown-of-thorns sea-star (*Acanthaster planci*)**

The crown-of-thorns sea-star– so named because of its spiny arms– feeds on the soft parts of corals. It sits over a live coral, digests it, and then moves on, leaving the bleached white coral skeleton behind. A decade ago, there was an epidemic of these sea-stars, and vast stretches of coral reefs in the Pacific Ocean were left barren.

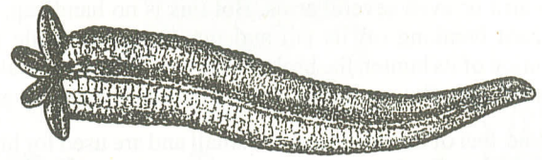


Fig.374 **Comet star (*Linckia*) regenerating four arms**

How nice it would be if, on injury to a limb, we could cut it off and grow another one in its place! The sea-star can do this. A sea-star which has lost one or more of its arms can grow a new one. Not only that; a detached arm, provided it has a part of the central disc sticking to it, can grow a new disc and arms and become a complete new sea-star. One kind of sea-star, called *Linckia*, regularly breaks off an arm which then grows a miniature disc with four arm buds. This stage is called the "comet" form, and soon grows into the five-armed adult. Of course, sea-stars also reproduce sexually, releasing their ova and sperms into the sea. And they are very prodigious; a single sea-star may produce more than two hundred million eggs in a year! Luckily for oysters, only a few of these survive.

As sea-stars are fond of eating oysters, they are the bane of oyster-fishermen. Earlier, whenever these fishermen caught sea-stars in their nets, they would cut them into two and throw them in the sea, thinking that they had killed the sea-stars. Little did they realise that they were actually helping to increase the sea-star population by doing so! Nowadays, they use "tangles"– iron bars to which are fixed many chains covered with frayed rope. The ropes catch on the rough spines of the sea-stars as the tangle is dragged along the sea bottom. When the tangle is brought up into the boat, sea-stars are brought to the shore and thrown on dry land. Sometimes lime is sprinkled on the sea bottom; this does not harm oysters but burns the sea-stars.

The pore-plate or madreporite on the upper surface of the sea-star's disc is situated between two of its arms. A line joining the pore-plate and the centre of the disc, and then continued, will pass through one arm (ray). We can call this arm an *anterior ray*, and the other arms in a clockwise direction as 2,3,4 and 5. The pore-plate is thus located between arms 3 and 4 or, in other words, in the inter-radius 3-4. The rays 3 and 4 constitute a *bivium* and the other rays a *trivium*. In feather stars, a line drawn from the anus to the mouth and extended, passes through one of the ambulacral grooves This is the anterior ray, and rays 2,3,4, etc., run clockwise from1. Here the anus is in inter-radius 3-4. If the anus is centrally located, the line joining the hydropore and mouth is used instead.

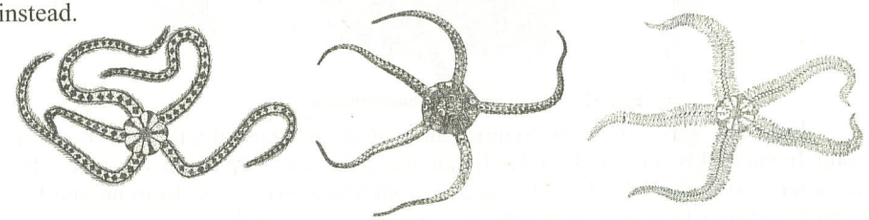


Fig.375 **Marbled brittle star (*Ophiocnemia marmorata*) Smooth (*Ophioglypha*) and thorny (*Ophiocoma*) serpent stars**

First cousins to the sea-stars are the brittle stars or serpent stars. They can be easily distinguished from sea-stars. While in sea-stars we cannot make out where the central disc ends and the arms start, these have a distinct button-like disc from which arise five slender worm-like arms. If you touch or catch one, the animal will shed part of an arm, a whole arm or even several arms. But this is no handicap; it can grow them again. Like a lizard breaking off its tail and running away while the wriggling tail distracts the attention of its hunter, the broken arm wriggles like a snake while the brittle star moves away to safety. But, unlike sea-stars, a broken arm cannot grow a new body.

The tube-feet of the brittle star are small and are used for breathing and sense of touch, not for walking. But it moves its arms quickly (at about 2 metres per minute) in a sinuous movement to crawl much faster than a sea-star. This snake-like movement of the arms gives the brittle star its other name– serpent star.

Like the sea-star, the mouth is on the lower surface, but there are no ambulacral grooves on the underside of the arms. The arms have a jointed appearance, and they may be smooth or thorny. Unlike the gruesome feeding habits of sea-stars, brittle stars take in mud, and the diatoms and minute animals in the mud are digested in the stomach. There is no intestine or anus, and the undigested waste is thrown out of the mouth.

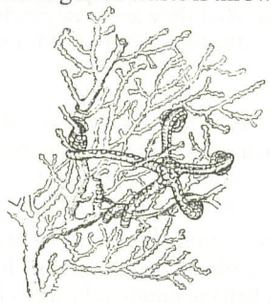


Fig.376 **A brittle star coiled around a sea fan**

Brittle stars dislike light, so they are found under stones. Some live in the crevices of sponges, or on sea fans and hydroid colonies with their arms twined around the branches and having the same colour, so that they are camouflaged.

Fig.377 **Basket star (*Gorgonocephalus*)**

Their disc varies from one to three cm, with the arms usually three to five times as long. In the basket star (not found in Indian seas), the disc is up to ten cm and the five arms, after arising from the disc, divide and subdivide repeatedly to form hundreds of flexible branches which extend straight outwards or curl up tightly.

Fig.378 **Feather star (*Antedon*)(After Carpenter)**

Fig.379 **Feather star (*Antedon*) in resting position (left) and when disturbed (right) (After Moore). Note resemblance to inverted tulip position of sea star**

Another relative of sea-stars is the feather star. The name comes from the arms, which are bordered on each side by a row of short side-branches, known as pinnules, giving the animal a fern-like or feathery look. There are usually ten arms, but some feather stars may have 40, 80 or even 200 arms. The mouth, anus and ambulacral grooves are on the upper side. On the lower side, where the arms start branching, are short, unbranched, hook-like attachment devices, called cirri, by which the feather star can hold on to a stone. They remain attached by the cirri to the stone, with the arms spread out more or less horizontally with their tips somewhat flexed. When detached from their hold, they swim gracefully by raising and lowering some of the arms alternately with the remaining arms. While arms 1,3,5,7 and 9 are being raised, arms 2,4,6,8 and 10 are being struck downward. But the animal soon tires and attaches to a stone.

The arms of the feather star exude a sticky slime, to which diatoms, green algae and minute animals stick. Tiny hairs called cilia then propel this food-containing slime via the ambulacral grooves to the mouth. Like sea-stars and brittle stars, feather stars can also shed their arms when grasped, and grow new ones. Even if eight arms are lost, they can regenerate, but if all ten arms break off, then the animal dies.

Feather stars are even prettier than sea-stars, being white, cream, yellow, orange, green, bright red, wine red, maroon, purple, violet, brown or black. Many forms are striped, and have other animals hiding on their arms, with a similar striped colouration for camouflage.

Fig.380 **Sea-lilies *Ptilocrinus* (left) (After Clark) and upper portion of *Cenocrinus* (right) (After Crapenter).**

While feather stars are found in shallow seas, their cousins– the sea-lilies live in deeper waters, from 200 to 5,000 m. They look like feather stars stuck on the end of a long stalk, which may be 50 cm long. It is interesting to know that giant sea-lilies, with stalks 21 m long, grew millions of years ago, as can be seen from fossils in rocks. Like the Coelacanth fish which was believed to be extinct until a live specimen was caught off South Africa in 1938, the discovery of living sea-lilies, earlier known only as fossils, must have been one of a marine biologist's most sensational thrills.

47 Rough Stuff—Pin-cushions in the Sea

And, lilting where the laver lingers,
The starfish trips on all her fingers;
Where, 'neath his myriad spines ashock,
The Sea-egg ripples down the rock.

Rudyard Kipling

Walking along the seashore, you will find some funny-looking creatures lazing about. One kind looks like a round ball with pins stuck all over it, while the other resembles a shapeless sausage thrown by some careless picnicker. Both seem to be immobile, but if you have the patience to wait and watch, you will find that they are crawling ever so slowly. The pin-cushion kind is a sea-urchin, while the long one is a sea-cucumber.

Both of them belong to an assemblage of animals of which the most familiar are sea-stars (more popularly, but wrongly named starfish). All of them occur only in the sea and exhibit a radial as well as pentameral symmetry, i.e., the organs of the body are arranged like the spokes of a wheel around the central axis, and are five or multiples of five.

All the animals in this group also have an internal system of tubes in which water can be pumped in. Hundreds of such tubes end in tube-feet tipped with suckers. With the help of this unique hydraulic system the suckers on the tube-feet can cling to rocks on the sea bed or attach to food. Sea-urchins can creep slowly on the sea bottom with the help of their movable spines or tube-feet or a combination of both. Even vertical rocks can be climbed by using the tube-feet.

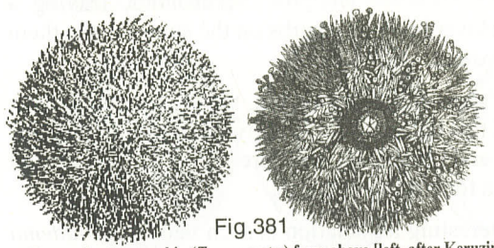


Fig.381

Short-spined sea urchin (*Toxopneustes*) from above [left, after Keruzinger] and from below [rigt] showing mouth with teeth and tube feet interspersed among spines

If the spines of a sea-urchin are brushed off, we can see its "shell" or test with a beautifully intricate pattern of knobs and tiny holes arranged in five double rows which run like the meridians of longitude from the top of the globe to the bottom (where the mouth is located). The rows of tube feet are not spread all over the test; the bands on the test which have tube-feet pores are known as the ambulacral areas, while the intervening areas (without pores) are interambulacral. The sea-urchin's spines fit on the knobs and can be rotated, when threatened. Some sea-urchins clump several spines together and point them at the enemy. Their diet is varied; some feed on leafy seaweeds or scrape algae off rocks, and most are scavengers on carrion but do not mind a slow moving snail, barnacles, sponges or tube-worms. Just inside the mouth are five teeth which are part of a complex array of hard limy plates and muscles, called Aristotle's lantern and used for feeding—so called because Aristotle first described it. It consists of five interconnected pyramids, each ending in a constantly growing tooth. The entire apparatus consists of 20 skeletal pieces.

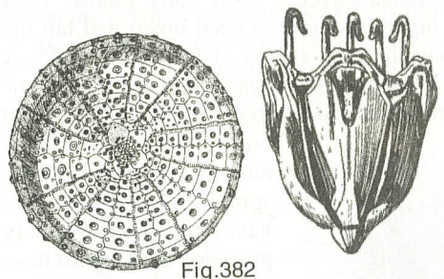


Fig.382

Test [shell] of sea urchin Aristotle's lantern [after Forbes]

One might think that, with their formidable array of spines, sea-urchins would hardly have any enemies. But they form the food of helmet shells (*Cassis*) and triggerfish. The helmet shell crawls towards a sea-urchin, lifts the front edge of its shell and foot from the sea bottom and, rearing high with the foot lifted in an arch, drops on to the sea-urchin, pinning it down. Its rasp-like radula (tongue) then cuts a hole in the sea-urchin's test, and feeds on the soft inner parts.

A triggerfish coming across a sea-urchin nudges it with its snout, trying to roll it over and attack the lower portion where the spines are shorter than on the upper part of the body. The spines are carefully broken off one by one, till only the test remains. The fish then crushes it and feeds on the inner soft parts.

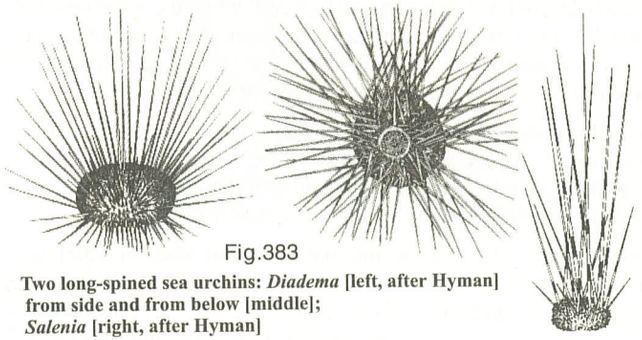


Fig.383

Two long-spined sea urchins: *Diadema* [left, after Hyman] from side and from below [middle]; *Salenia* [right, after Hyman]

The spines of sea-urchins differ in length. In some, they are short, while in others, such as *Diadema*, they may be as long as 30 cm on a 10-cm round test and look like knitting needles. These spines can pierce thin-soled shoes and are poisonous, leaving a festering wound. Moreover, minute backward pointing barbs on the spines make them extremely difficult to remove from the wound.

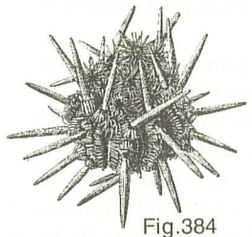


Fig.384

Slate-pencil sea urchin [*Goniocidaris*] after Thomson]

In the slate-pencil sea-urchin, the spines do not have sharp pointed tips but are short, stubby and soft like crayons. They were, and probably still are used by coral-atoll schoolchildren for writing on slates.

An interesting association is seen between *Diadema* and razor-fish, or snipe-fish (*Centriscus scutatus*). These are long, extremely thin bodied with long tubular snouts and bodies covered with bony plates. They hover, motionless head down and tail up, among the long spines of *Diadema*. The way they disappear all of a sudden is weird. At one moment you see a dozen of them with their flat body, like a knife blade among the sea-urchin's spines. In a trice they have vanished. With military precision all of them have turned their body so that, while they are still at the same place, the razor-thin profile of the body is turned towards your eyes and you feel that they have disappeared.

Snipe fish [*Centriscus scutatus*]

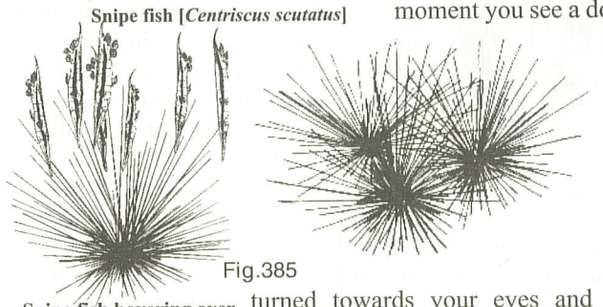


Fig.385

Snipe fish hovering over long-spined sea urchin

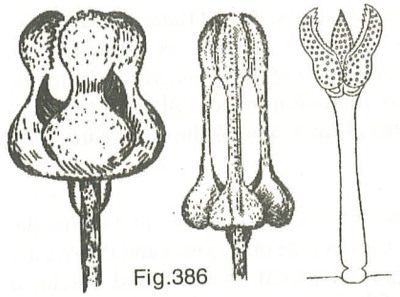


Fig.386

Two kinds of sea urchin pedicellaria [after Boone]. Compare with pedicellaria of a sea-star [right]

Nestling among the spines of sea-urchins are tiny pincer-like organs called pedicellaria. There are four kinds, the commonest having 3 (but sometimes 2, 4 or 5) movable jaws on a flexible stalk. While some have poisonous glands and catch tiny prey or attack enemies, others pick up bits of dirt settling on the sea-urchin and throw them away.

Some sea-urchins drill deep holes in rocks and live at the bottom of this tunnel, many such tunnels occurring close together. It is not known how the animals bore into hard rock; it is not due to any acid secretion dissolving the rock, but is believed to be patient and persistent gnawing away by the teeth or steady abrasion by the spines. The tunnel may have a small opening some 15 mm wide, but widen out to accommodate an animal 8 cm in diameter and go down 60 cm below the opening. Others bore shallow hemispherical pits in which they can just fit,, but are so numerous that the rock is honeycombed with sea-urchin holes.

Unlike the symmetrical, globular sea-urchins which are called "regular" sea-urchins, there is a group of "irregular" sea-urchins comprising the sand-or heart-urchins and the cake-urchins, sea-biscuits or sand dollars. Although, as in sea-stars, there is a subtle bilateral symmetry in regular sea-urchins even though the body apparently looks radially symmetrical, irregular sea-urchins are distinctly bilateral, with front and rear ends.

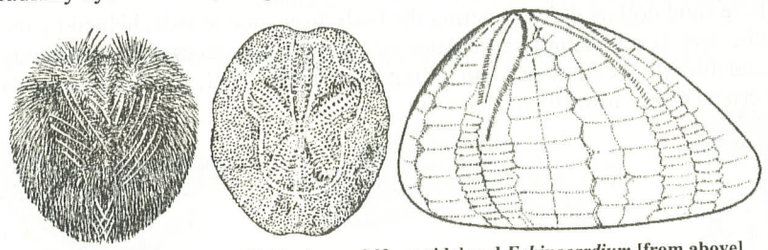


Fig.387 **Heart urchin [*Echinolampas*] [from side] and *Echinocardium* [from above]**

In heart urchins the lower portion of the oval body is flattened, while the upper part is arched and shows a five-leaved petal-like pattern. The tube-feet on the petaloids are not used for creeping but for breathing. The mouth may sometimes be displaced forward and the anus backward. Spines are small, curved and held parallel to the body as if they have been combed backwards. Narrow bands of minute spines, shaped somewhat like a tennis racket, maintain a water current and remove debris settling on the body.

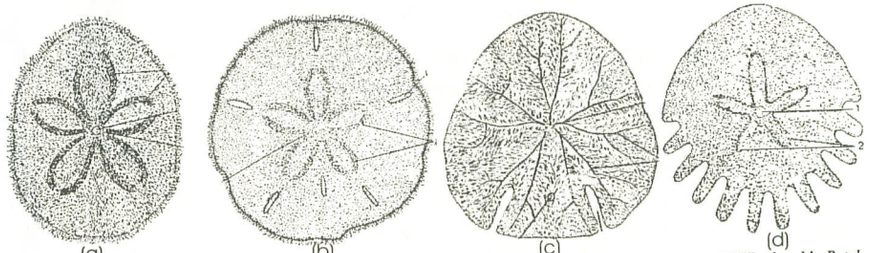


Fig.388 (a) Sea biscuit *Clypesster rosaceus* (b) Keyhole sand-dollar *Mellita* (c) Sea pancake *Echinodiscus* (d) Wheel urchin *Rotula*

Cake-urchins, also called sand dollars or sea-biscuits, have a flattened, disc-like body covered with very short spines. Five petaloids as in heart-urchins are present on the upper surface. The lower surface has five grooves radiating outwards from the mouth; sometimes each groove branches into two. In keyhole sand dollars, the body is perforated by 2 to 6 slits, while in the wheel-urchins or sand-wheels the disc bears many blunt projections like spokes.

Heart-urchins and cake-urchins live buried in the sand and crawl just below the surface. When burrowing, the heart-urchin erects itself on the oral spines and throws the sand sideways with its curved lateral spines. It then rests in a cavity in the sand, leaving a hole on the surface of the sand. The wall and roof of the burrow is lined with slime so that the sand does not fall on to it or touch its body. Long tube-feet are thrust out through the surface hole to pick up small food particles, and then retracted and brought to the mouth.

Sand dollars also live buried just under the sand, crawling just under the surface so that we can see a trail. A sand dollar buries itself by piling up sand into a mound with its tube-feet in front of itself. Then, using its spines it shoves itself into this pile while the tube-feet continue to cover it with sand. It can be completely buried in 15 minutes. They feed on minute organisms and organic particles in the sediment. Like their flattened body, their Aristotle's lantern is also flat. Its jaws somewhat resemble birds in flight and are often called the "doves" of the sand dollar. While in regular sea-urchins the Aristotle's lantern can be extended from the mouth to rasp encrusting organisms, sand dollars cannot do so.

Keyhole sand dollars dig by rotating the body from side to side, helped by the spines and tube-feet. If accidentally turned upside down by the waves it slants its body and drives sand through the front slits and, piling it up behind itself, gradually raises its body into a vertical position and then falls over.

48 The Good, the Bad, and the Ugly

But I, that am not shaped for sportive tricks,
Nor made to court an amorous looking-glass;
I, that am rudely stamp'd, and want love's majesty
To strut before a wanton ambling nymph;
I, that am curtailed of this fair proportion,
Cheated of feature by dissembling nature, ...
William Shakespeare *KING RICHARD III*

Fig.389
Sea cucumber *Holothuria nigra*

Wandering along the seashore, you are likely to come across an elongated, black or brown leathery sausage-like object. Pick it up, and a stream of water squirts out from one end, so that what was turgid a moment ago is a shapeless flaccid mass. It is actually an animal called sea cucumber.

You might be amazed to learn that it is related to sea-stars and brittle stars. These have pentaradial symmetry, i.e. like five spokes of a wheel, while the sea cucumber is long, has two distinct ends, and seems to be bilaterally symmetrical (i.e. two equal halves, like us). But look closely, and you will find five ridges, equally distant, running from end to end. And in many sea cucumbers, these ridges bear tube-feet hollow finger-like protuberances connected to a complex hydraulic system which can pump in sea water to swell them or pump it out to deflate them.

Cucumaria pulcherima (left, after Miner),

Cucumaria frondosa (middle, after Hyman)

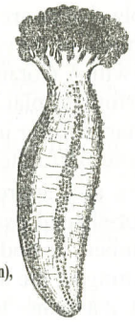


Fig.390
and *Phyllophorus urna* (right, after Thomson), showing ridges bearing tube feet

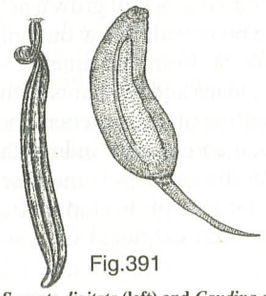


Fig.391
Synapta digitata **(left) and** ***Caudina arenata*** **(right, after Monticelli), showing variations in shape and length of body**

Sea cucumbers form a heterogeneous assemblage. All have a mouth at one end and an anus at the other, but some are hardly 2 cm long while others may be over a metre. Most sea cucumbers have tube-feet but in some, where the lower part of the body is flattened to form a creeping sole, only the tube feet on the sole are used for locomotion; those elsewhere are modified into sensory warts and papillae. In many sea cucumbers, there are from 10 to 30 tentacles which can be withdrawn into the mouth.

These are modified tube feet. They are coated with slime to trap minute drifting animals, or sweep on the sea bottom to entangle microscopic plants and animals. From time to time, the tentacles are withdrawn into the throat and then, as they are pulled through the tightly puckered mouth, they are “licked clean", the food being wiped off and retained inside. Other sea cucumbers ingest the bottom mud and sand; as it passes through the gut, organic matter gets digested and the rest is voided in the form of a cone.

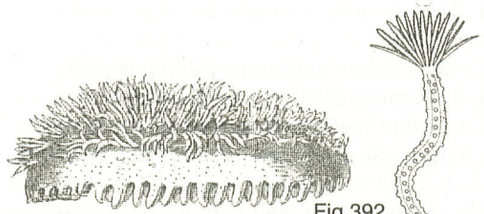


Fig.392

Ilyodaemon **(left, after Theel), showing flattened sole for creeping.** ***Eusynapta*** **(right, after Hyman), showing warts**

The skin of most sea cucumbers has innumerable microscopic limy skeletal elements called deposits, in the form of ossicles or spinules. They are of different shapes and are used by specialists to identify different species. They can be extracted by dissolving the skin in caustic soda solution, and are given fancy names.

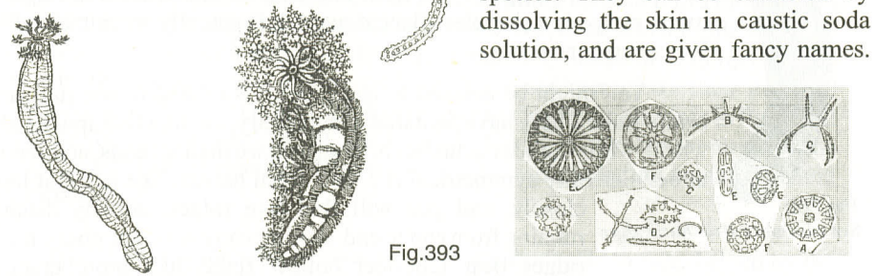


Fig.393

Synapta inhaerens **(left, after Miner) and** ***Cucumaria crocea*** **(middle, after Thomson) showing simple, and elaborately branched, tentacles respectively. Ossicles in the skin of sea cucumbers (right)**

Simple shapes are smooth, warty or spiny rods which may have knobs at the end like a dumbbell, or they may be branched or be flat plates with many holes in them. An oval plate with 4, 6 or more holes in two rows is called a *button* (a *buckle* or *clasp* in German). A perforated plate having an erect perforated spine on it is called a *table* (a stool in German; a *tower* in French). A short rod divided into short branches is a *rosette*, while a concave perforated plate with a toothed edge is a *basket*. Tiny wheels with 6 to 24 spokes are, appropriately, called *wheels*. Synaptid sea cucumbers have *anchors*– anchor-shaped ossicles attached to oval perforated plates. If you pick up such a sea cucumber , its body will stick to your fingers as if it is coated with glue. This is because stretching of the animal's body wall brings the points of the anchor up to the surface, where it attaches to our fingers. Sea cucumbers, when irritated or disturbed, throw out all the viscera (body organs), but this does not handicap the animal as it will grow a new set. (Actually, the vigorous contraction of the muscles of the body wall throw out only the intestinal tract and the gonads, either from the mouth or from the anus. The respiratory organs, all parts of the water vascular system, the cloaca and remnants of the mesentery remain inside the body.) Apart from excessive handling of the sea cucumber inside or out of the water, high temperature or depleted oxygen can also induce the expulsion. The viscera are poisonous. Fishermen in Indo-Pacific coral reefs mash sea cucumbers or cut them into two and squeeze the contents into tide pools to stupefy fish and catch them. A potent anti-cancer drug, holothurin, has been extracted from sea cucumbers.

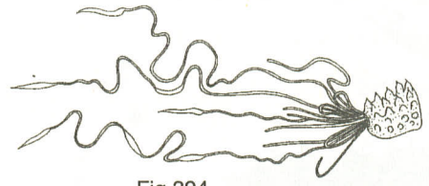


Fig.394

Hind end of a sea cucumber discharching Cuvierian tubules (After Russo)

Many sea cucumbers also have another means of defence, in the form of what are known as tubules of Cuvier, named so after their discoverer. When a sea cucumber is irritated, it contracts and emits some white, pink or red tubules with closed ends from the anus, just like toothpaste squeezed out of a tube. The blind ends swell, dart about in all directions, and the tubules rapidly elongate to form sticky threads. In the "cotton spinner" varieties of sea cucumbers, the threads wrap around the offender a lobster or crab, binding it and preventing its movement, while the sea cucumber crawls away to safety.

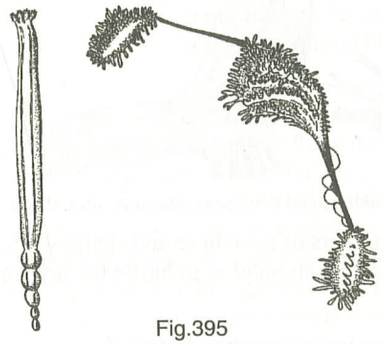


Fig.395

Self-mutilation in ***Leptosynapta inhaerens*** **(left, after Pearse) and** ***Cucumaria planci*** **(right, after Monticelli)**

In other sea cucumbers, the Cuvierian tubules do not move, elongate or stick, but are highly poisonous to fish and other animals. In humans, they may produce blisters, inflammation of skin and eyes.

Under conditions of stress, many sea cucumbers undergo autotomy (self-mutilation). The body constricts at one or more places and portions break off. In many animals, autotomy results in each broken-off portion growing into a complete animal. In sea cucumbers, however, only the portion containing the mouth is able to repair itself to form a complete sea cucumber.

Dried and smoked sea cucumbers, known as trepang or beche-de-mer, are an epicure's delight in the east, especially in Chinese cuisine. They are added to soups or stews, when they swell to a jelly-like consistency. Containing up to 50% protein and very little carbohydrate, trepang is highly nutritious and is said to taste like smoked herring mixed with fish glue. Doesn't sound delicious, but then one man's meat is another's poison! I had a bitter experience of a similar culinary kind. Marshall Bulganin and Nikita Kruschev of Russia had visited our Aquarium and presented two bottles of caviar in olive oil.

My mentor opened one bottle, tasted it and apparently disliked it. So he had both bottles thrown away. Imagine his chagrin the next day when the chauffeur of a famous film actor of those times turned up. The actor had heard about the caviar and offered to buy them at a price equivalent to my one month's salary. Both he and I were, to say the least, sorely disappointed.

The pearl fish (*Carapus*) has found safety and security after making friends with sea cucumbers. It enters the body of a sea cucumber tail first. Its unwilling host resents the unwelcome guest's forceful entry, and tries to resist its entry by closing the anus. But it has to relax sooner or later, to open the anus and pump sea water into its respiratory organs for breathing. The pearl fish slowly works its way in little by little and finally lodges among the host's respiratory trees. Usually a sea cucumber plays host to a single fish, but as many as three fish have sometimes been found in one animal.

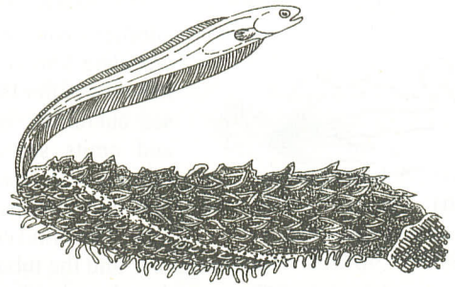


Fig.396 **The pearl-fish (*Carapus*) entering a sea cucumber, tail first**

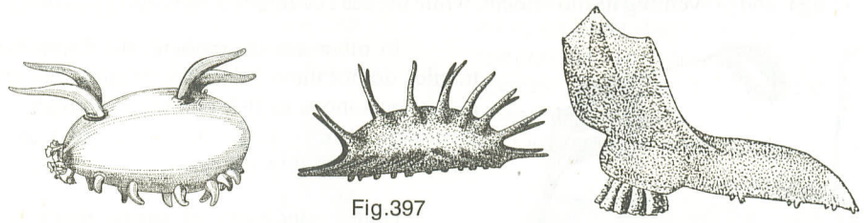


Fig.397

Some deep-sea sea cucumbers: *Scotoplanes* (left), *Deima* (middle) and *Peniagon* (right) (all after Theel)

Unlike the typical sausage-shaped sea cucumbers of nearshore and shallow sea, those of the deep sea have bizarre shapes, which are so atypical as to baffle the novice marine biologist.

There is even an aberrant pelagic (swimming) sea cucumber, *Pelagothurias*.

Fig.398
A swimming sea cucumber *Pleagothuria* (After Chun)

49 Footprints on the Sands

No grain of sand
But moves a bright and million-peopled land,
And hath its Edens and its Eves.

Blanchard

Sandy beaches, to a casual observer, seem to be barren wastes, compared to rocky shores and mud flats which often teem with crawling, burrowing or sessile (sedentary) life. But, apart from the burrowing ghost crabs, below the sand face lies a hidden world of animals. The naked eye may not see it, but the sand grains are swarming with tiny microscopic animals. They are collectively termed meiofauna or, because they live in the minute spaces between the sand grains, interstitial fauna.

They were discovered as late as 1933 by Adolf Remane. They can be collected by taking some sand at low tide and placing it in a narrow plastic container. After a day or two, the animals collect in the top layer where there is adequate oxygen for them to breathe. The top 5 cm are scooped up and an isotonic magnesium chloride solution is added so that the animals which are thigmotactic (i.e., clinging tightly to the sand grains) relax their hold. The sand is stirred with filtered sea water and sieved first through a sieve of 0·5 mm mesh to retain coarse objects, and then through a sieve of mesh size of 65 microns (a micron is a thousandth of a millimetre) where the animals are retained on the sieve. As they are transparent, they may be stained with Rose Bengal.

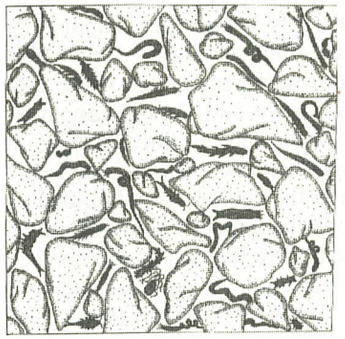


Fig.399 **Interstitial life between sand grains**

These animals are immigrants from the sea. They are not uniformly distributed throughout the intertidal region. Most of them are found on the lower shore towards the mid-tide level, at depths of 10 to 30 cm below the surface. They are tiny– most of them are less than a millimetre. They are not crushed by the sand grains, nor do they move the sand grains aside, but crawl easily over the sand grains in the capillary system of minute spaces between the sand grains.

For ease in movement in a restricted space, they have elongated, flattened, worm-like bodies. No light penetrates the sand below 15 mm, so they are blind, as sight would be of no use in the darkness; their bodies are also pale, transparent and colourless. They avoid light, so they live at a depth where they are not washed away by surf. To compensate blindness, they have sensitive hairs, bristles, setae and papillae, as well as balancing organs called statocysts. To avoid being washed away, their bodies have adhesive structures such as papillae, plates, discs, hooks, claws and glands at the end of the body secreting a glue. For protection against abrasion by moving sand grains, there are scales, spines, bristles and spicules.

The mobile forms move continuously among the roads and streets between the sand grains by creeping, crawling, looping, gliding with the help of cilia, wriggling, writhing and jerking. But any disturbance in the sand grain configuration makes them adhere to the sand grains. Though blind, they somehow avoid touching each other.

Many are gregarious, forming small communities of their own kind. Though some are predators, the majority feed on detritus; many are herbivorous, feeding on single-celled diatoms. Breeding takes place throughout the year, but may be inhibited by cold or by dilution of sea water. Hence summer is more conducive, whereas monsoon is detrimental. There are no planktonic larval stages, and the eggs, larvae and young are adhesive.

No two beaches have exactly the same conditions, and even in the same beach conditions change with tide and seasons. Sand grain size is an important factor affecting the population of meiofauna. If the sea near the shore is shallow, the beach will be flat, wide and with fine sand grains. Where the sea is deep, the beach is narrow, steep and with coarse sand. The larger and heavier sand grains are deposited near low-tide level, whereas smaller, lighter grains are washed further up near high-tide level. There is more water between the sand grains at low-water level and more with increasing depth. Sand dunes high on the beach are heated by the sun and are dry, so they do not support meiofauna. Fine sand gets clogged with silt and detritus and cannot hold water. Porous sand (with large grains), on the other hand, allows free movement with consequent heating and drying during daytime, increasing the temperature and salinity. At greater depths and at the lower end of the beach (i.e., away from the shore), there is saturation of sea water in the interstices between the sand grains; circulation of air is obstructed, resulting in a build-up of carbon dioxide and, sometimes, hydrogen sulphide.

As with other intertidal animals, meiofauna too are fairly tolerant to fluctuations in temperature (eurythermal) and changes in salinity (euryhaline). But each animal colonises a level of the beach where conditions for its survival are optimum, giving rise to a zonal distribution. They also migrate from zone to zone within a beach. Sheltered beaches have a larger population because conditions are more stable. Larger interstitial animals show a preference for coarse sand near low-tide level, while smaller ones are more numerous in medium-grained sand and at higher levels on the beach. Populations in fine-grained sands are poor due to clogging and impeded water circulation, stagnation and poor oxygenation. Meiofauna occur down to a metre below the sand surface. Because of the absence of free swimming larvae and their thigmotactic (clinging) habit, it may be inferred that meiofauna would have a limited range of geographic distribution. Yet many of then are cosmopolitan, occurring in beaches all over the world. Study of meiofauna also gives a clue to the amount of pollution on a beach. The copepod-nematode ratio is particularly useful; the higher the number of the latter, the more polluted is the beach, as nematodes are more tolerant of low oxygen levels. As is the general rule, the harmful effects of pollution lead to decrease and even disappearance of sensitive species, a consequent decrease in the diversity (variety) of fauna, with an increase or monopoly of a few opportunistic or resistant species which are immune to the effects of pollution.

To see a world in a grain of sand
And heaven in a wild flower,
To hold infinity in the palm of your hand
And eternity in an hour.

William Blake.

Over 30 groups of interstitial animals ranging from single-celled Protozoa to molluscs and echinoderms are found in beaches. Among Protozoa, ciliates are the commonest. Long and ribbon-like, they glide over the sand grains with the help of their cilia. Hydroid coelenterates are also common. *Halammohydra* have a ciliated

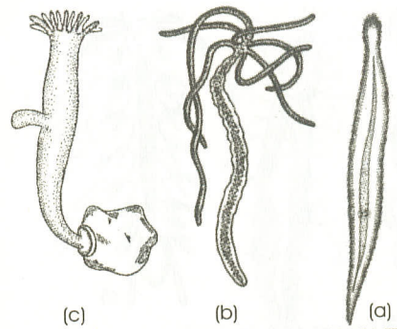


Fig.400 **(a) Protozoon ciliate *Trachelioraphis*, (b) *Halammohydra* (c) hydroid *Anthohydra***

body with two whorls of tentacles and one whorl of statocysts. The mouth, unlike in other Hydras, is situated at the aboral end.

Turbellarian flatworms, with flat, ribbon-like bodies and long tails are also well suited to an interstitial life. *Acanthomacrostomum* is an aberrant form with an endoskeleton of calcareous spicules. Another aberrant group is the Gnathostomulida with cuticular jaws in their pharynx. The small chaetonotid gastrotrichs typically have two adhesive tail forks, but macrodasyid gasrotrichs with (usually) three patches of adhesive tubes, are larger (0.5 to 2 mm). Interstitial kinorhynchs

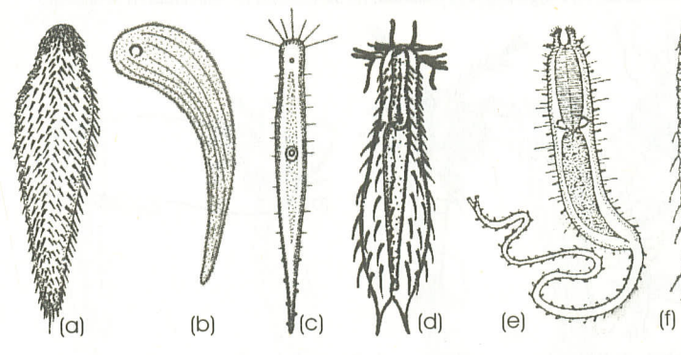
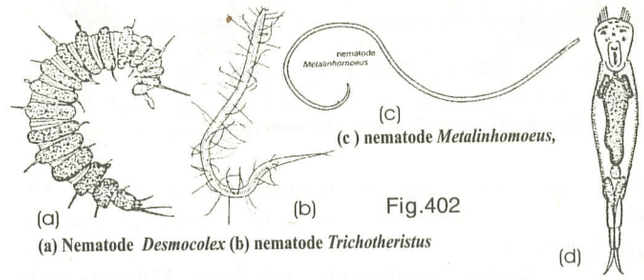


Fig.401 **(a) Turbellarian *Acanthomacrostomum* (b) flatworm *Convoluta* (c) *Gnathostomula*, (d) gastrotrich *Chaetonotus* (e) gastrotrich *Macrodasys* (f) kinorhynch *Cateria***

are sparse, but *Coteria*, with a long body with cuticular spines, is fairly common.



(c) nematode *Metalinhomoeus*,

Fig.402

(a) Nematode *Desmocolex* (b) nematode *Trichotheristus*

(d) rotifer *Encentrum*

Nematode worms are abundant in meiofauna. With a thread-like body for crawling, they also have adhesive glands on the tail for clinging to sand grains. Nemerteans are fairly common, though rotifers are not.

Interstitial Polyozoa, unlike their sessile colonial cousins growing attached to stones and shells, are solitary and mobile. *Monobryozoon* uses its tube-like stolons for movement and adhesion as well as for reproduction. Archiannelids have thigmotactic tail appendages. Oligochaete worms use their dermal setae to cling to sand, while polychaete worms have parapodial setae and caudal glands for the same purpose.

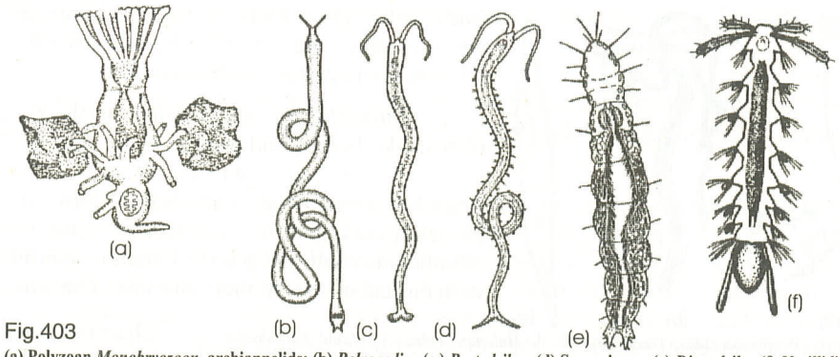
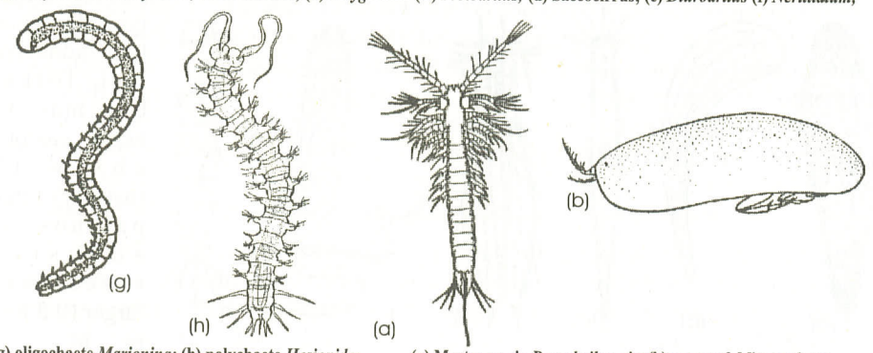


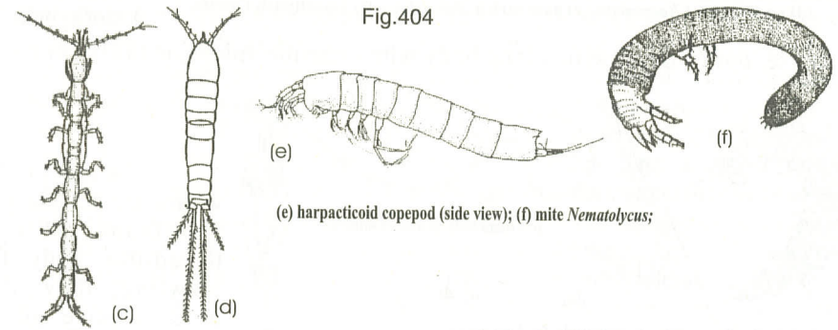
Fig.403

(a) Polyzoan *Monobryozoon,* archiannelids; (b) *Polygordius* (c) *Protodrilus;* (d) Saccocirrus; (e) *Diurodrilus* (f) *Nerillidium;*



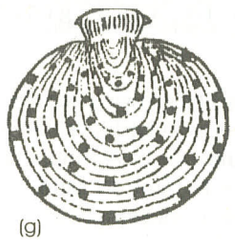
(g) oligochaete *Marionina;* (h) polychaete *Hesionides* (a) Mystacocaria *Derocheilocaris;* (b) ostracod *Microcythere;*

Fig.404



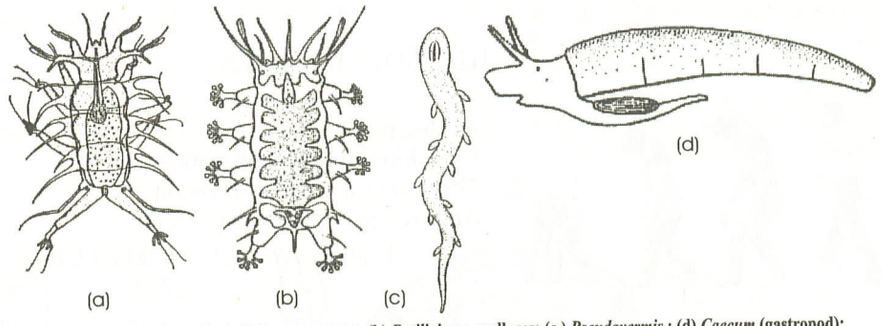
(e) harpacticoid copepod (side view); (f) mite *Nematolycus;*

(c) isopod *Angeliera;* (d) copepod (top view);



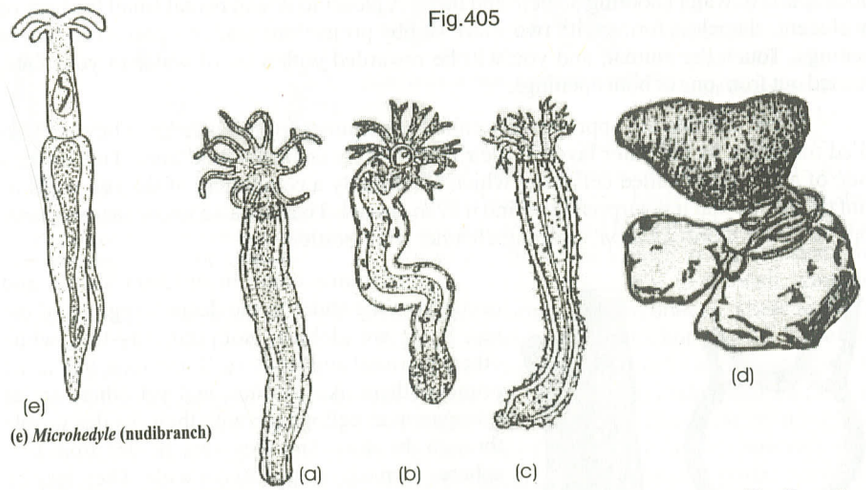
(g) branchiopod *Gwynia*

Among crustaceans, we have Mystacocarida, ostracods with small, elongated wedge-shaped shells, worm-like isopods clinging to the sand grains with their claws, and amphipods. Sand-dwelling copepods have slender, worm-like cylindrical, flexible bodies, special sensory club-like asthaetes on the tentacles and flattened ovisacs. Small worm-like mites such as *Nematalycus* and pycnogonids also occur in sand. The rare, sedentary articulate brachiopod *Gwynia* is only a millimetre in size.



Tardigrades: (a) *Parastygarctus;* (b) *Batilipipes;* molluscs; (c) *Pseudovermis* ; (d) *Caecum* (gastropod);

Fig.405



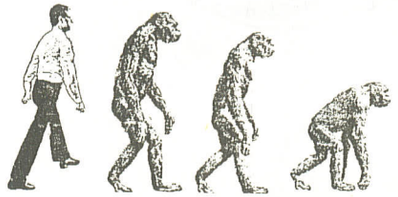
(e) *Microhedyle* (nudibranch)

Fig.406 Sea cucumbers: (a) *Rhabodomolgus;* (b) *Psammothuria;* (c) *Labidoplax;* (d) ascidian *Heterostigma*

Tardigrades (water-bears), having four pairs of legs with adhesive discs are plentiful. Interstitial molluscs are usually long, worm-like and lack shells, but some have long, tubular shells.

Apodous sea cucumbers are small and have five pairs of statocysts below the tentacles. Ascidians (sea squirts), unlike their sessile cousins on rocks, can move slowly, using their long rhizoids for locomotion and adhesion.

50 Our Forefathers



As an active ascidian again
Fresh forms he began to contirve,
Till he grew to a fish with a brain,
And brought forth a mammal alive.

Kipling *A BALLAD OF EVOLUTION*

If you walk along the seashore, you will notice spurts of water shooting up here and there. A closer look will reveal small leathery or translucent, shapeless forms with two short, stubby projections (called siphons) ending in openings. Touch the animal, and you will be rewarded with a jet of water in your face, squirted out from one or both openings.

These animals are appropriately called sea squirts, from this habit. They are also called tunicates, as the outer layer of their body-wall is enclosed in a tunic. This tunic is made of a substance called cellulose, which is normally a component of the cell walls of plant tissues, so that it is surprising to find it in an animal. They are also known as ascidians, from the Greek word *askidion*, meaning a leather wine-bottle.

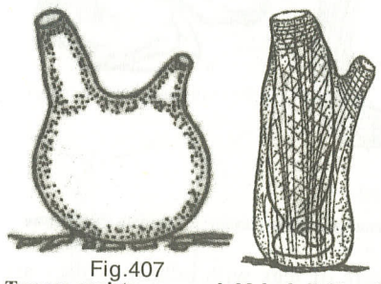


Fig.407
Two sea-squirts: sea-peach *Molgula* [left] and sea-vase *Ciona* [right]

Sea-squirts come in different shapes and occur from the shore to the deepest regions of the sea. Some are globular, soft and jelly-like, while others are hard and leathery. Some look like dried prunes,. others like peaches, and yet others are as transparent as cellophane with their insides visible through the skin. And they vary in size from tiny spheres to massive ones 30 cm wide. They may be whitish, grey, brown, yellow, orange, purple, green, lavender, red or black.

A sea-squirt has two openings; water is taken in from one, called the inhalant aperture or oral opening and passes out of the exhalant or atrial aperture. The inner walls of the body are pierced with thousands of tiny slits like a sieve, and as the water passes through, it acts as a strainer, filtering out minute organisms in the water and retaining them for food. The sea-squirt also has a heart and blood system. The heart is peculiar in that it pumps blood to and fro. It beats, sending a succession of rhythmic waves from left to right for abut 90 to 120 seconds. The beats become slower, and the heart stops for a few seconds. Then it starts beating once again, but from right to left. The beats become stronger, until the next period of rest, when it again reverses its beats.

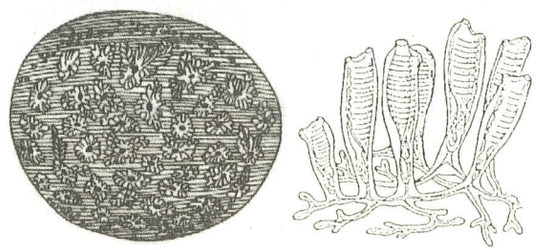


Fig.408 **A colonial ascidian *Botryllus* [left] and *Cavellina* [right]**

Some sea-squirts live together in colonies. They are jelly-like and cover the undersides of rocks, wharf piles, sea-shells or seaweeds, which look as if they have been coated with glue. Others may be white, yellow, green, brown, purple or crimson red. When Victor Hugo, in his epic "Toilers of the Sea" wrote that "the walls are splashed with crimson stains as if giants had been fighting there", he was describing compound ascidians. Many a time, the colour of the animals is in vivid contrast to the jelly-like background: white on scarlet, purple on yellow, golden on jade-green. Whatever may be their colour, they can be identified by the small, star-like dots which cover the entire surface. While the individuals in a colony have their own separate intake openings, several individuals share a common exit opening. Others are branched, or have lobes or tubercles, or grow on the ends of stalks, or form lumps 15 cm in diameter.

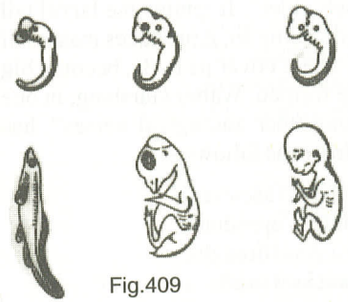


Fig.409
Embryos of fish, bird and man show a remarkable resemblance in the early stages [upper row], and can be distinguished only at an advanced stage [lower row] (after Romanes)

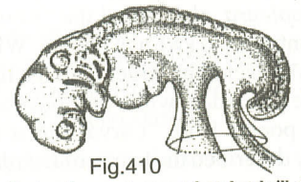


Fig.410
Foetus of a man shows notchcord and gill-slits

You may not believe it, but all these, and many more which we shall see later in this chapter, are our remote ancestors. I am sure you will ask: how can these primitive, jelly-like lumps which cannot see, hear, walk or think, be our ancestors? We humans, together with fishes, amphibians, reptiles, birds and mammals share a common trait; all have backbones (vertebrae) and are therefore known as vertebrates. But, apart from this, there are other common characters which separate us from backboneless animals (invertebrates). These are: (1) a notochord. The backbone is formed from an organ, called notochord a stiff but elastic unjointed rod that later calcifies or is filled with cartilage (in sharks and sting rays). (2) Paired gill-slits connecting the pharynx (throat) to the exterior. Fishes and amphibians (frogs, toads and newts) have well developed gill-slits. They disappear in most adult amphibians, but are seen as vestiges in the embryos of reptiles, birds and mammals. (3) A tubular nerve-cord running along and above the backbone. (4) A hepatic portal circulatory system, where veins collect blood from the intestines and then go to the liver, where they ramify.

The first two characters are also found in some animals which are not backboned animals, but seem to be a link between these and the invertebrates. These are the ones dealt

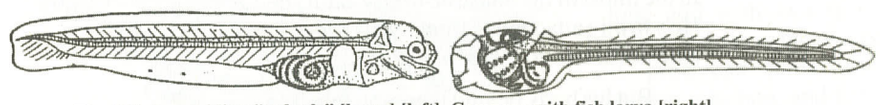


Fig.411 **An ascidian "tadpole" [larva] [left]. Compare with fish larva [right]**

with here, and belong to the phylum Chordata (so called because of the notochord).

Coming back to our ancestors the ascidians, we shall have to see the babies of these ascidians. As in many animals, the young do not resemble their parents, but look radically different and are known as larvae. The young of an ascidian, unlike the adult, swims freely in the sea. It is shaped somewhat like a frog's tadpole and is in fact called an ascidian tadpole. It has a tail flattened from side to side, fringed with a tail fin with a series of striae just like the fin-rays in a fish's fin.

More important; along the tail runs a cylindrical rod of gelatinous nature enclosed in a layer of cells– the notochord. It also has paired gill-slits, and there is also an eye-spot, brain, ears, mouth and digestive tract, heart and complex nervous system. In short, it resembles anatomically an early stage of certain vertebrates. At the front end

there are three processes called adhesive papillae. After swimming about for some time, the ascidian tadpole attaches itself to a substrate with the help of these papillae. The notochord disappears, the tail vanishes, and so do the eye, brain, ears and mouth. The body rotates to bring the mouth end away from the point of attachment, and the result is the shapeless mass which we call a sea-squirt.

Fig.412
***Oikopleura* removed from its "house"**

While most ascidians seem resigned to their fate and meekly submit to the retrograde metamorphosis from an actively swimming larva to a sedentary adult, there is one rebel which refuses to do so. This is *Oikopleura*, also called the "Housebuilder". It retains the larval tail and continues to swim in the sea. While doing so, it produces masses of jelly-like ascidians larger than itself. These cover its body, become big and are discarded, while new ones are formed. Walter Garstang, in one of his poems from "Larval forms and other zoological verses", has vividly described the habits of *Oikopleura*, as follows:-

Oikopleura, masquerading as a larval ascidian,
Spins a jelly-bubble-house about his meridian;
His tail, doubled under, creates a good draught,
That drives water forward and sucks it to aft.

A filter in front collects all the fine particles
Micro-flagellates and similar articles
Which pour in a stream through a jelly-built tunnel
Into his mouth and its mucilage funnel.

The funnel begins with his endostyle gland,
Which flicks mucus up to his circular band:
The stream through his mouth trails it out into threads,
And the whole is rotated as fast as it spreads.

In effect this rotator's a neat centrifuge
That lets out the water and keeps in the ooze:
The water's sucked outwards by paired water-wheels,
The residue serves him with plentiful meals.

Now although Oikopleura sits by himself
In the midst of his house on a jelly-built shelf,
He's firmly attached in front by his snout,
And never lets go till his house wears out.

But his body behind is completely free
And bathed by the water that comes from the sea
Through two lattice-windows let into the walls,
Which limit the size of incoming hauls.

Into this water-space the effluents flow
That start from the spiracles' outward throw:
And lest water-pressure the bubble should burst,
Tubular valve in front blows first.

What shall we say of this marvellous creature
Who breaks all the rules by his composite nature?
The puzzle increases the more it's observed
How far from the track of his fellows he's swerved.

When his jelly-house starts as a lump on his back,
His tail is the finger that stretches it slack:
He probes with its tip between body and test
And lowers the parts which too closely are pressed.

Then, after windows and traps are all ready,
The tail pops inside and, with motions more steady,
Sets the pump working, the water streams in,
The jelly-house swells, and the fishings begin.

We believe we can satisfy any scutator
That anatomy, house, and pharyngeal rotator
Are pure Doliolid in all their relations,
With highly original specialisations.

His tail is the problem and also the base
For nothing will work if this you erase:
It seems that, from lack of metamorphosis,
His larva and adult in ½ and ½ doses.

There are other ascidians which swim in the sea. *Pyrosoma* are compound tunicates; the colony is shaped like a tube closed at one end, which may be 5 to 35 cm long and 0·5 to 7·5 cm in circumference. The individual animals (called zooids) are arranged side by side with their gill apertures outside and atrial openings inside the tube. The animals are transparent, but shine at night. *Pyrosoma* is popularly known as sea sock. There are eight species; one found in New Zealand grows to 18 metres. Fishes like the black durgon (*Melichthys ringens*, a triggerfish) feed on them.

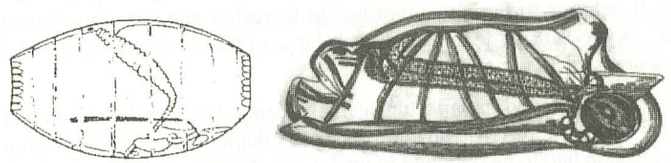


Fig.413 **A barrel-shaped salpid, *Doliolum* [left] and a solitary salp *Salpa* [right]**

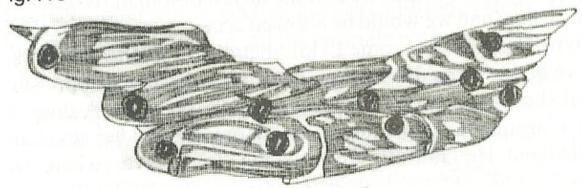


Fig.414 **Portion of a chain of salps**

The salps (*Salpa*) also swim in the sea and reproduce alternately asexually and sexually. A solitary salp is spindle-shaped or cylindrical, about 2·5 cm long and with two siphon-like processes at the rear end. It produces buds which remain attached, and form a double row containing hundreds of salps, somewhat like a bandolier of cartridges. Inside the transparent body of each individual can be seen a small compact mass of viscera tinged with pink. The whole chain, a metre or more long, swims with a wavy, snake-like motion, caused by the contraction of conspicuous transverse muscle bands in the body wall. Each individual in the chain now lays an egg which grows into a solitary form.

Ascidians are hermaphrodites, both sexes being found in an individual. All the animals described above are placed in the sybphylum Urochorda (of the phylum Chordata), as the notochord is found in the tail region of the larva.

Krusadai Island, near Rameswaram, is called a paradise for marine biologists,

because of the rich variety of sea life found here. It is especially noted for the occurrence of the acorn worm (*Ptychodera flava*), first described by Eschscholtz in 1825 in the Marshall Islands. It seems to be widely distributed in the Indian and Pacific Oceans, from Red Sea and Mozambique to the Galapagos Islands, but in India it is restricted to this small region.

Fig.415 **An acorn worm *Balanoglossus* [after Spengel]**

The body of an acorn worm (popularly known as *Balanoglossus* to specialists) is soft and worm-like and has a proboscis, joined by a collar to the long trunk region. The proboscis is conical and may be elongated or of the shape of an acornhence its common name. The proboscis is connected to the collar by a narrow flexible neck. The mouth is situated on the neck, and leads to a straight gut which ends in an anus at the end of the trunk. Just behind the mouth is the pharynx. On its dorsal side is a narrow tubular prolongation with stiff cellular walls, jutting into the hollow probnoscis; this is the notochord. Behind the collar, the sidewalls of the pharynx are pierced by a series of gill-slits; these increase in number throughout the life of the animal.

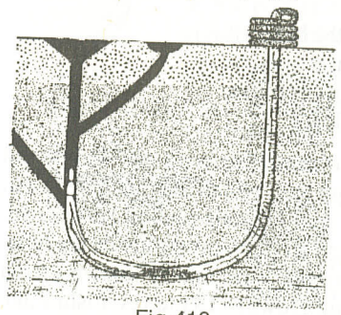


Fig.416 **Burrow of acorn worm [after Stiasny]**

The acorn worm lives inside a U-shaped burrow which it excavates. The main entrance to the burrow is funnel shaped, but there are more accessory openings on the sides of the main burrow. Its presence can be made out by its castings or faecal coil at the other mouth of the burrow.

The presence of notochord and paired gill-slits on the pharynx shows that, though it looks like a worm, it is a Chordate. It belongs to the Hemichorda. On the other hand, its top-shaped larva, called a "tornaria", is very similar to the auricularia larva of Echinoderms, so that the acorn worm links Echinoderms with vertebrates.

I was keen to visit Krusadai, and an opportunity finally came. I was leading a batch of postgraduate students. As the fauna of Krusadai had been badly depleted by over-collection over the years, prior permission had to be obtained to visit it. On the way, we had to attend a seminar at nearby Mandapam Camp, where, by luck, we met the doyen of Indian fisheries at that time. He told us to mention his name, and we would be allowed access. Krusadai was not connected to any place by road, so we had to trudge some 12 kilometres along sandy beaches, with a few narrow creeks where we had to wade thigh deep. Finally we reached the opposite shore, and clapped our hands and shouted to attract the local people's attention. A dugout canoe took us across and we met a formidable lady who was in charge. Behind her stood an old man wielding a double-barreled gun. He faithfully followed the woman everywhere, so we named him "Mary's lamb".

We introduced ourselves to the woman, and she asked us if we had the necessary permission. We gave the name of the doyen, but he turned out, as far as she was concerned, to be a *persona non-grata*. It transpired that he was the Director of the Central Government's Fishery organisation, while Krusadai was looked after by the State Government. I pleaded, then threatened that I would report her to the higher-ups, but to no avail. I even told her that I would go back to Madras by the next train and return by the night train. She coolly told me that the ferry did not operate after sunset. When I told her that I would swim across, she informed me that there were sharks. To add to my discomfiture, all the time "Mary's lamb" stood by fingering his double-barrelled gun. (We learnt later that he was the woman's father, and these two were the only educated persons in the fishing village, so he was protecting her against any mishaps in that God-forsaken village.)

We were crestfallen, and had to be content with restricting our shore study to a region where there were no acorn worms. This was just the beginning of our ordeal. As no food is available on the island, we had stocked our larder amply for our stay there. (Or so we thought.) Tiring walks on the shore in the hot sun, reinforced by the insatiable appetite of my young students, soon exhausted our stock, and we were thinking of shortening our stay at Krusadai, when a naughty trawler captain, eyeing our girl students, offered us a joyride on his boat and, as this would mean an opportunity for the students to refresh their fish nomenclature, I accepted his invitation without demur. On board we had a cunning, if somewhat dishonest, idea. Coyly one girl student approached the skipper for specimens of fish which *could* be useful additions to our museum, as many fishes in the Bay of Bengal are not met with in the Arabian Sea. He gladly complied with the request. He would have been horrified to see these 'specimens' in the frying pan that evening instead of reposing in a jar of preservative!

Fig.417 **Lancelet *Branchiostoma (Amphioxus)***

Finally we come to the lancelet (*Amphioxus* or *Branchiostoma*). It is a semitransparent animal, about 5 cm long, with a fish-like body but no distinct head. Along the body are V-shaped muscle segments, with the points of the 'V' directed forward. A fin extends along the back and enlarges at the rear end to form a tail fin. There is also a ventral fin extending up to an atriopore (the rear opening of the atrium or branchial cavity). At the front end is a funnel-like oral hood, with the mouth at its bottom. The hood is lined with many bristles (cirri). The mouth leads into a pharynx occupying the front half of the body, and pierced by over a hundred gill-slits. The intestine opens into an anus a little to the left of the tail fin. A notochord runs all along the body from the front end of the 'head' region to the tip of the tail. (In verterbrates, the notochord extends forward only as far as the mid-brain, stopping short at the pituitary body.)

As the notochord extends even into the "head" region, the lancelet is placed in the subphylum Cephalochorda (notochord in head). It has all the four features of Chordates indicated earlier, viz. a notochord, a tubular dorsal nerve-cord, paired gill-slits in the pharynx, and a hepatic portal blood system. Thus it is the most advanced of all the Protochoradates (i.e. all the animals we have seen so far).

There is a so-called "eyespot" in front of the end of the notochord, but this is not a true eye, being only a pigment spot. The lancelet sees by many "spinal eyes", situated at regular intervals and consisting of a pigment cell next to a visual (or seeing) cell.

Lancelets are seldom seen and therefore thought to be rare. But they occur in fair numbers at many places on the east coast of India where a low-tide sand bar shelters the mouth of an unpolluted bay, protected from wave action. It lives with the greater part of its body buried in sand, only a bit of the front showing above the surface. When disturbed, it quickly burrows head first into the sand, disappearing instantaneously from view. Stamping the ground with the foot will bring them out of hiding for a moment, when it will writhe about on the surface for a moment, and then dive back. Rarely, it is seen resting motionless on one side on the sand surface, or swimming with a darting motion.

Perhaps many people will not feel particularly proud at the thought of being descendants of such animals as those we have seen above, no matter how remote this

relationship may be. When Charles Darwin first propounded his thesis on the Origin of Species and Descent of Man, Samuel Wilberforce, the bishop of Oxford questioned him thus: Was it through his grandfather or grandmother that he claimed descent from an ape?

As Byron says in "Don Juan"

His speech was a fine example, on the whole,
Of rhetoric, which the learned call "rigmarole".

Darwin was absent at this meeting of the British Association for the Advancement of Science, but Thomas H. Huxley, on his behalf, replied, in the now well known classic rebuff: "I would feel no shame at having an ape for an ancestor but I would indeed be ashamed of a man who plunged into scientific questions of which he knew nothing". From this, we all should learn a lesson:

Now I hold it is not decent for a scientific gent
To say another is an ass– at least to all intent;
Nor should the individual who happens to be meant
Reply by heaving rocks at him to any great extent.

Bret Harte

Anyway, there is a consolation for those of us who might feel awkward about our forebears; we humans are *not* descended from monkeys, but monkeys and we are branches of a common ancestral stock!

51 Monarchs of the Aquatic Realm

When the sands are all dry, he is gay as a lark,
And talks with the utmost contempt of the shark;
But when the tide rises, and sharks are around,
His words have a timid and tremulous sound.
'Tis the voice of the lobster, from Lewis Carroll's

ALICE'S ADVENTURES IN WONDERLAND

In any series of articles on marine life, sharks are bound to come up sooner or later. The very word 'shark' conjures up visions, in the minds of most people, of a huge wide-mouthed sea monster whose rows and rows of jagged razor-sharp teeth are always ready to bite the nearest man within reach. Yet people do not realise that many more sharks (tens of thousands per year) are killed by men than are people (40 to 300) killed by sharks.

Dogs– man's best friend– bite over three million people in India every year, but not a word appears in the newspapers. And more people are killed in motor car accidents, or even hit by lightning. Yet, such is the fear of sharks that their very thought sends shivers down our spines. I remember one fine morning in November 1964, when we had caught over 450 kg of sharks, averaging two metres long, in two hours at Angria Banks, some 110 km off Vengurla in Maharashtra. In the afternoon, we were chatting on the deck of our fishing boat when I suddenly heard a splash, followed by screams. Seeing one of our deckhands clad only in shorts thrashing about in the water, I assumed he did not know swimming and had been thrown overboard. We soon had him out of the water, and I learnt that he was an expert swimmer and diver, whose services were often requested whenever a net or rope got entangled in the boat's propeller and had to be freed underwater. Yet he had got so panic stricken that he even forgot he knew swimming, and screamed to be pulled out.

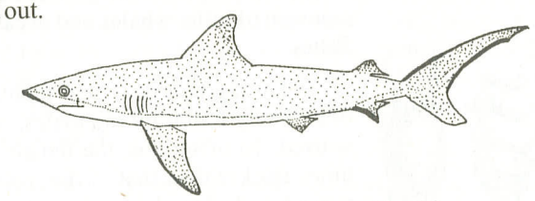


Fig.418 **Pelagic shark *Eulamia limbatus* (Muller and Henle)**

Sharks differ from bony fishes in that their skeleton (skull and backbone) is made of cartilage (gristle); there are no bones. Instead of a gill-cover, sharks have (usually) five gill-slits on each side. Their tail has a longer upper lobe (unlike the forked tail of bony fishes). And, unlike the flat, plate-like scales of bony fishes, sharks have microscopic, tooth-like scales.

All fishes swim effortlessly, but in comparison with sharks' sinuous grace, other fish's locomotion seems crude. There is a reason for the lopsided tails of sharks; the tail curves up towards the tip, so that there is a long upper fin-lobe. This has the effect of

raising the tail as the fish moves forward. To counter the tendency of the front of the body pointing down, the paired fins spread out on either side as planes to act as elevators of an airplane to lift the fish

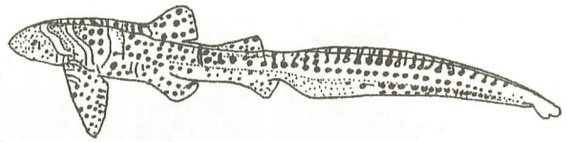


Fig.419 **Sea-bottom shark, *Stegostoma varium* (Seba)**

Pelagic sharks (those that swim at or near the water surface) have to swim constantly day and night. Once they stop swimming, they are doomed to die. This is because these sharks lack the throat muscles which enable bony fishes and bottom sharks such as the zebra sharks (*Stegostoma*) and catsharks (*Chiloscyllium*) to pump water over their gills. Pelagic sharks swim with their mouths open, and their forward motion maintains a constant flow of water over their gills. In the aquarium, if a shark is exhausted and sits on the tank bottom we 'kick start' it by holding it and repeatedly propelling it forward a short distance until it revives. Incidentally, if a shark is held belly up, it goes limp, as if hypnotised, and can then be easily handled.

Stroke a shark backward, and the skin feels smooth, almost like the fur of a kitten. But stroke it from tail to head, and it feels as rough as sandpaper. This is because the minute scales tilt backward. These scales are like miniature teeth; in fact a shark's teeth are just overgrown scales. Sharkskin, called shagreen, was used earlier as sandpaper for polishing wood, on matchboxes and on sword handles to prevent slipping. With the scales removed, sharkskin is used for leather handbags, shoes, belts, wallets and watch straps. And sharks need not worry about toothache. Behind the front row of functional teeth are five to six "spare" sets, continuously moving forward so that when the front teeth drop out, new ones take their place.

Besides man, sharks have other enemies, primarily other sharks. Small individuals are constantly preyed upon by larger sharks, often of the same species. Certain large sharks, such as bull and tiger sharks, even show a marked liking for shark flesh. During the breeding season, the danger of cannibalism to the pups (young) is so high that some species segregate the adult males from the pregnant females, and these females, in turn, do not feed at all at that time. Small sharks have been found in the stomach of killer whales and occasionally of large bony fishes.

During courtship and mating, female sharks are often badly bitten by the males, so that they are badly scarred. To offset this, the female's skin is two to three times thicker than that of the male, its thickness being more than the length of the male's teeth.

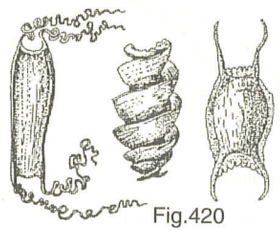


Fig.420

Mermaid's purses [egg cases] of some elasmobranchs [sharks & rays]

Some sharks lay eggs called mermaid's purses, mermaid's pin-boxes, sailor's purses or sea cushions. These egg cases may be spirally flanged and pear-shaped, or barrel-shaped, and have threadlike filaments or horns at the corners to anchor them

to seaweeds. The young may take six months to a year to hatch.

In other sharks, the eggs, instead of being laid on the sea bottom, hatch inside the womb and are expelled into the water. In the lamnoid sharks, e.g. the sand tiger shark (*Odontaspis*), mako (*Isurus*), mackerel or porbeagle shark (*Lamna*) and thresher shark (*Alopias*), the first young to hatch feeds on the other (unhatched) eggs, so that only two young are born (one from each of the two horns of the womb).

Nearly two-thirds of all sharks give birth to live young, from six to as many as 40, depending on the species. And, unlike in bony fishes, the sex of sharks can be easily distinguished; the tips of the pelvic fins on the male's belly have a pair of sausage-shaped extensions called "claspers" for transferring sperm to the female. Only one clasper is used at a time.

Most sharks are believed to live less than 25 years. The relatively small school shark (*Galeorchinus*), based on tag returns, is indicated to live to 32 years, while the whale shark (*Rhincodon typus*) may live to 70 years. Almost all sharks live in the sea. There are, however, some exceptions. The bull shark (*Carcharhinus leucas*) is found in a variety of freshwater locations such as Lake Nicaragua, the Lake Izbal-Rio Dulca system in Guatemala, Lake Jamoer in New Guinea, and a number of rivers in North and South America, Africa, Asia, Australia and the Philippines. These were once believed to be distinct freshwater species. However, there is no anatomical difference between most of them and bull sharks which wander from freshwater to saltwater and back again. There is some evidence that the Ganges River shark (*C. gangeticus*), closely related to *C. leucas*, is a true freshwater species.

Many bony fishes have a gas-filled swim-bladder which enable them to float without having to swim all the time. Sharks do not have a swim-bladder, but this is compensated by a large liver, sometimes as much as one-fourth the size of the body, filled with oil rich in vitamin A. In some sharks the vitamin content is a hundred times more than in cod liver oil, so that, to conform to international specifications, it has to be diluted with groundnut oil. The corneas of sharks can be used for corneal transplants in blind humans, as they do not swell when placed in varying concentrations of salt solution.

Sharks do not have good eyesight, but their sense of smell is acute. Further, running along each side of the body is a lateral line canal, which is sensitive to vibrations such as those caused by a thrashing fish (or swimming human). Moreover, pits in the skin of the head, called ampullae of Lorenzini, can detect electrical disturbances of less than five thousandth of a microvolt, enabling the shark to locate hidden prey such as a sole (fish) buried beneath sand.

Sharks also have a good sense of sound (hearing). Long before scientists had even demonstrated that sharks can hear, Polynesian natives were using sounds to attract sharks. They use a shark rattle called a "wuk'wuk". It consists of broken coconut shells strung together on a rope or cane hoop, with cowrie shells sometimes interspersed to provide a more rapid higher-pitched jingling sound.

Two methods are used to produce the sounds. One involves vigorously working the shark rattle up and down on the sea surface. This produced sounds similar to those of a shoal of fish breaking the surface. In the other method, intermittent bursts of low-frequency sound typical of a fish in distress are generated by shaking the rattle underwater by scraping it against the side of the boat.

The natural sounds to which sharks are attracted are usually irregular and non-continuous. Therefore the Polynesians undoubtedly found through trial and error that close attention had to be paid not only to the rhythm of shaking the rattle under water but also to the relation of periods of sound with periods of quiet.

Sharks normally feed on fishes, molluscs and crustaceans; very few feed on marine mammals. Of some 350 kinds of sharks only nine– the great white (growing to 6·4 metres and 3,300 kg), mako, bull, lemon, tiger, dusky, blue, white tip and hammerhead are involved in attacks on humans. A 3.2-metre long white shark has a biting force of 1.5 tons. Sharks are also excellent scavengers; their stomachs have contained beer bottles, boots, bags of potatoes or coal, kerosene tins, raincoats, even chicken coops.

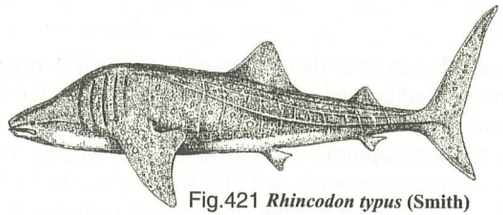


Fig.421 ***Rhincodon typus*** **(Smith)**

Fortunately for us, the largest of all sharks, the whale shark, does not eat large prey. Growing to 18 metres and weighing 13 tons, this fish, like the basking shark (the second largest at 7·5 metres), feeds on plankton and small fish. These are filtered out by comb-like gill-rakers. Consequently, their teeth are no bigger than a baby's fingernails. In contrast, the smallest shark is *Squaliolus laticaudus*, whose adult is only 15 cm long.

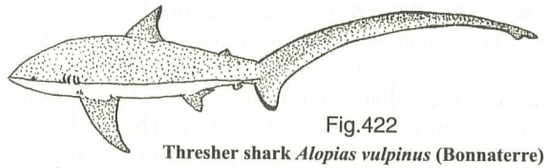


Fig.422

Thresher shark ***Alopias vulpinus*** **(Bonnaterre)**

The thresher or fox shark (*Alopias*), 4·6 m in length, has a tail longer than the head and body put together. The tail is used to beat the water so as to frighten a shoal of fish into a compact mass before eating it.

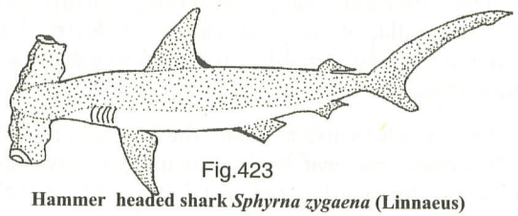


Fig.423

Hammer headed shark ***Sphyrna zygaena*** **(Linnaeus)**

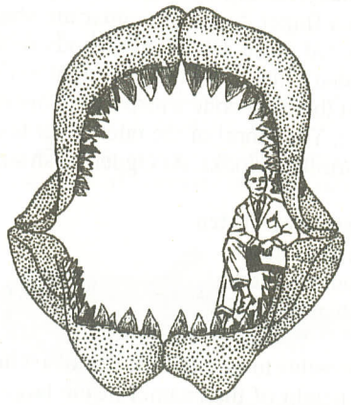
In the hammer-headed shark (4·6 m), the eyes and nostrils are situated at the tips of a head set at right angles to the body like a draughtsman's T-square. Together with the swaying of the head from side to side when swimming, this enables the fish to sample a wider path of water to see and smell its prey. Also, the flattened head, like the ailerons on an aircraft wing, increases its manoeuvrability.

We have caught small sharks, about 60 cm long, in knee-deep water at Chowpatty beach in Mumbai. But even these have to be handled cautiously. I remember one evening, at the Taraporevala Aquarium, I saw a crowd of collegians, with one person, looking pale and shaky, having his finger bandaged. Enquiries revealed that our captive shark had bitten his finger. Since our aquarium sharks never jump out of the water to bite people, I wanted more details. Somebody told me that the casualty had dipped his hand into the shark tank. "Serves him right, trying to show off before the girls", was my response. At that, someone whispered in my ear that the victim was not a student, but their professor. The moral of the tale: never tease or otherwise provoke a shark, however small or harmless it looks. As Ogden Nash succinctly put it,

> How many scientists have written
> The shark is gentle as a kitten!
> Yet this I know about the shark:
> His bite is worser than his bark.

Incidentally, it is possible to estimate the size of a white shark's body length from the size of its teeth. The height of the enamel of the largest tooth in its upper jaw is directly proportional to the fish's length, with every 1.25 inch (slightly less than 32 mm) indicating approximately 1 additional foot (30 cm).

52 Body Talk



There was a young lady from Guam,
Who said, "The Pacific's so calm.
I'll swim for a lark".
She met a large shark,
Let us all sing the 93rd Psalm.

We have all seen couples in the park, cuddling in the moonlight. Not a word is spoken, but each one knows what's on the other's mind. That is body language. Animals use body language too, as anyone who has tried to get past a guard dog would know. As you approach, the dog utters a low, rumbling growl. If you persist in going ahead, the growl turns louder, and changes to barking. If you still do not heed this warning, you do so at your peril; you are likely to be bitten.

In human terms, we think that the dog is guarding his master's property. Actually the dog believes that it is *its* territory, and guards it against intruders. Many animals, birds, and even fishes establish and guard a territory. A fish's territory may range from a few centimetres to many metres.

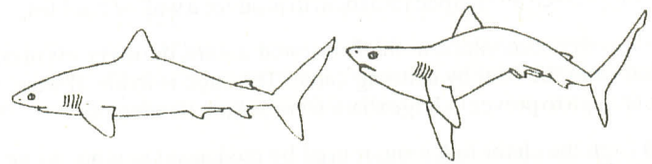
Sharks also have a territory, but, as they are swimming all the time, their territory also moves with them. Before we studied sharks' behaviour and their motives, it was assumed that all shark bites were made by hungry sharks wanting to feed. In many attacks, however, the shark only bit once and then swam away. Gradually, over the years, the body language of sharks has been better understood. They were merely trying to express their annoyance at being approached; it was just that we could not 'read' their language and suffered due to our ignorance.

When a scuba diver suddenly approaches a shark, and the latter feels threatened, two modes of warning behaviour are expressed. One is posturing display. The shark lifts its snout, bends its head upward and arches its back like an angry cat does. The normally horizontal pectoral (front paired) fins drop vertically, and the tail is bent to one side.

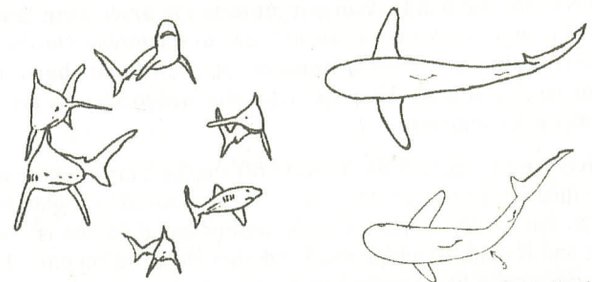
Apart from posturing, the shark also changes its way of swimming. The bending of the tail on each side leads to a laterally exaggerated swimming. This is accompanied by rolling or spiral looping, a spiral up-and-down movement through the water.

The normal, straight path changes to an S-shaped path. If the swimmer continues to approach the shark, the S becomes more compressed, culminating in a figure-of-eight pattern. This is the shark's limit of patience, and if we are foolish, or ignorant, enough to swim still closer, an attack follows. And then we blame the shark for attacking us, and, like giving a dog an ill name and hanging it, call the shark a cold-blooded man-eater!

Fig.424 **THE WARNING SIGNS**



1. Posture of (left) normal, and (right) angry shark. Note the bending of the tail on one side in the latter



3. Spiral looping, as seen from front

2. Normal (above) and laterally exaggerated (below) swimming in a shark

4. Swimming paths: (a) normal (no display), (b) mild, (c) moderate, and (d) intense displays

We should thank our stars that the largest shark ever to have existed in the sea is extinct. The giant white shark (*Carcharodon megalodon*) may have reached a maximum size of 13.7 metres (45 feet) and weighed as much as 12,700 kg. Its teeth measured up to 20 cm (8 inches). Compare this with the 7.6 cm (3 inches) teeth of the present-day great white shark (*Carcharodon carcharias*) which grows to 7.6 m (25 feet). The extinct shark lived from about 25 million years ago until 5 million years ago.

Various strategies have been devised to keep sharks from attacking human beings. An obvious way is simply to build a fence around an area frequented by swimmers. But this is expensive and needs constant maintenance; a hole in the fence is enough to let sharks in.

In Australia and South Africa, meshing has proved successful. Nylon gill nets 150 m long and six metres deep are strung 300-500 m away from the shore, and kept in place for at least 24 hours, four times a month. The net does not stretch from the sea surface to the bottom, nor does it cover the entire length of the beach; but it works.

Bubble curtains have also been tried, but have failed to deter sharks from crossing them. Pipes are laid on the sea bottom. They have holes drilled in them at short intervals, and compressed air is piped into them to produce a wall of bubbles.

For underwater observation in shark-infested waters, the diver sits inside a shark cage, suspended from the boat by a strong cable. The cage is made of stout steel bars spaced closely enough to prevent a large shark from poking its snout in.

Copied from the chain-link armour used by mediaeval knights is one designed for scuba divers. It extends from neck and trunk to wrist and ankles, and has a hood for the head and gloves for the hands. While it protects the diver from being bitten, the crushing power of a large shark's jaws can still lead to fractures or bruises. Suits made from Kevlar (used in bullet-proof vests) are not proof against shark bites. The Neptunic, a two-suit system, has 23 laminated Kevlar plates attached to a Scuba diver's wet suit to distribute pressure over a large area.

Scuba divers use a "shark billy" to ward off sharks. This is just a pole with a nail at the end, and is thrust at a shark at close range. It is supposed to frighten the shark and cause it to retreat, but hardly works. A more sophisticated device is "bang stick". It works like a rifle and is made of a pipe inside another close-fitting pipe. The inner pipe carries an explosive charge like a cartridge. There is no trigger; when the bang stick is thrust vigorously against a shark's body, the outer pipe slides backward and fires the bullet into the shark to cause a fatal wound.

A carbon-dioxide fired bullet is a similar contraption. However, all these devices are useful only when a diver can see the shark approaching. It should also be remembered that a non-fatal hit may make a shark more likely to attack.

A more sophisticated approach involves using natural chemical repellents. Pardaxin is a chemical found in the body slime of the Moses sole (*Pardachirus marmoratus*). Scuba divers observed in the Red Sea that sharks accidentally attacking this fish immediately withdrew as if they had bitten on a distasteful morsel. Both in laboratory and field trials, this chemical has proved successful. The problem is to collect enough quantity of pardaxin. It has subsequently been found that similar chemicals, known as surfactants and commonly used as industrial detergents, share this capability. One such surfactant, sodium dodecyl sulphate, is ten times more effective than the freeze-dried toxin of the Moses sole. But it disperses rapidly in water, and cannot, therefore, be used as a shark repellent until a method to slow its dispersal in the seawater without altering its effectiveness has been devised.

It has long been debated whether sharks hunt their prey by sight or smell. But, until two decades back, no one imagined that a third, very ingenious sense is used– detection of electric currents.

Animals (including man) emit direct current (D.C.) into seawater, because of a voltage difference between body fluids and the sea and between different parts of the body. In addition, alternating current (A.C.) is produced by the beating of the heart, muscle contraction and slow movements of the body.

The organs for detecting these low-frequency electric currents, situated on the skin of sharks and rays, are called ampullae of Lorenzini. And they can detect electric disturbances as small as 0·1 microvolt per centimetre equivalent to the current given out by an electric torch battery cell at a distance of 1,500 km.

Anyone who has seen a shark locating a sole fish buried below the sand in an aquarium tank must have noted how unerringly the shark senses it. If the sole fish is covered by a plastic sheet (which prevents the electric current from leaking into the water), the shark has to hunt by smell. But if the sole fish is covered by a sheet of agar (which can conduct electric current but prevents the shark from seeing or smelling its prey), the shark will still go straight for its prey.

Even a minor scratch on the skin can double the voltage gradient, and so can vigorous movements. So while swimming in shark-infested seas, don't splash about, and leave the water at once if you get a cut that bleeds.

The uncanny habit of sharks to appear suddenly near a diver can be irritating till one gets used to it. At one moment, there is no fish in sight, and in the blinking of an eye a shark zooms in until you feel that it is going to attack you, only to veer away at the last moment. My first encounter with a shark not separated from me by a pane of glass in an aquarium, or a boat's hull in the sea is still vivid in my memory. It must have been 1¼ metres long, but things get magnified in water and appear bigger, so it could well be seen as 2 metres. In my state of mind, it appeared more like a monster. The result? I felt a surge of involuntary micturition. (I have purposely used obfuscatory language to hide my embarrassment; you may refer to the dictionary to find out what exactly happened.) Fortunately, in the wetness of the sea nothing extraordinary could be noticed, but my buddy, an experienced navy diver, must have sensed my nervousness, and put his thumb up to restore my confidence.

53 Kites in the Sea (and their kin)

The King of Ithaca, Laertes' son,
I mean Ulysses, 'twas myself that killed,
And not Telemachus with scale fish bone
Lucian

We can learn a lot by strolling on a beach when fishermen land their catch. And one particularly curious looking fish is the sting ray. Sting rays resemble kites a flat, oblique-square body and a long tail. There are many kinds of sting rays, and the largest grow to over 1·8 metres in body width. They give birth to live young. Cousins of sharks, they too lack bones, having a cartilaginous skeleton instead; but their skin is far smoother than sharks' skin. On the upper surface are the two eyes. Behind these are two round holes (called spiracles) which constantly open and close. On the lower surface are the mouth, and on either side of it, the nostrils. Behind the mouth are five pairs of gill-slits.

Fig.425 **Sting Ray**

Sting rays live and feed on the sea bottom, preying on crabs, worms and small fishes. They are admirably camouflaged. The upper side of the body is muddy brown, the underside white. Thus an enemy looking down at a ray will miss it against the muddy background; looked at from below, it will merge with the water or sky. Even its mode of breathing is modified. Other fishes take in water from the mouth and expel it from the gill-slits or gill-cover. If the ray were to breathe in this manner, it would suck in mud and choke the gills. Instead, water, free from the mud is taken in by the spiracles and passed out of the gill-slits.

Their flesh is edible. Their blood, like that of sharks, contains a lot of urea. When fishermen catch a sting ray they usually lop off the tail to let the blood flow out. If this is not done, the urea seeps into the flesh and gives it a peculiar taste. This is relished by people from Goa and Karwar, but not by others not used to shark or ray meat. The taint can be removed by soaking the flesh in salt water, or by holding it under running water for some time.

Except in butterfly rays, the tai is long and whip-like. But unlike in many bony fishes where a torn tail can regenerate, a ray's tail, once cut or bitten off, cannot grow again. The tails of bony fishes are supported by bony fin rays called lepidotrichia. Rays' tails are modified caudal fins, and are supported by horny, cartilaginous fin rays called ceratotrichia. But, although a ray's tail cannot regenerate, the spine(s) at the root of the tail can grow again if lost.

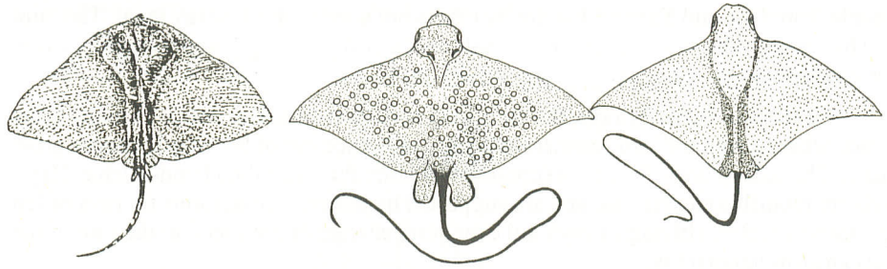
Unfortunately, sting rays, like sharks, are unduly maligned. This is because the long whip-like tail bears, on its upper side near the root, one (sometimes two or even three) spine with saw-toothed edges. This spine, in large rays, may be as long as 38 cm. On the lower surface of the spines are two grooves containing venom glands. (Let me digress a little to explain the difference between venom and poison. *Venom* is injurious to us when it is injected, or otherwise introduced, into our blood– usually by a jab from a needle-like spine. *Poison* causes harm only when eaten or drunk. Thus, some snakes are venomous– not poisonous, though many persons wrongly use the latter word. If you have no cuts in the mouth and no ulcers, you can safely swallow snake venom.)

The sting ray's venom is very potent– sometimes even fatal and I have often had to help fishermen who had been accidentally slashed by the tail spine while handling a thrashing sting ray in fishing boats.

A sting ray once involved me in a real-life 'Crime does not pay' episode. To collect live fish for display at our Aquarium, we use a barrier net, which is like a wall several hundred metres long and two metres high. As the net extends over too vast an area to be properly guarded, an assortment of 'poachers' takes a heavy toll. The culprits are mostly gulls and crows, but these are joined by people too. They wade through the knee-deep water and deftly remove fishes with a hand-net when the fisherman is not looking.

On one of these fishing trips, we collected some live pompano and kept them in a tub along with a sting ray, pending the arrival of our van to transport them to the Aquarium. As we were busy catching more fish at the other end of the net, the tub was left temporarily unguarded. A small urchin, obviously inexperienced, decided to filch some fish without taking the trouble to catch them. He put his hand into the tub, disturbing the fishes, and the sting ray jabbed. The boy was soon rolling in the mud, howling with pain, and his finger had swollen to an alarming size. There was no alternative for us but to abandon our collection and pack him off to hospital, there to ruminate over the oft-repeated adage, 'Crime does not pay.' And that is how a fish made, I'm sure, an honest citizen out of a not-so-straightforward boy!

Ulysses, whose wooden horse idea helped to end the Trojan war, is said to have been slain by the tail-spine of a fire-flair (sting ray). Paradoxically, the sting ray is not belligerent; it never uses its formidable weapon to kill its prey, and never takes the initiative in attack– only for defence. Most sting ray victims are stabbed when they accidentally step, while wading in the sea, on a sting ray lying in the mud. I always advise persons walking in shallow seawater to shuffle their feet.



Butterfly ray **Eagle ray** **Cow nosed ray**

Fig.426

In the butterfly rays (*Pteroplatea*), the body is much wider than long, and the tail is very short. Some of them grow to 100 cm (body width). While sting rays and butterfly rays swim by wave-like motions of the body, eagle rays (*Myliobatis, Aetobatis*) and cow-nosed rays (*Rhinoptera*) use their fins as 'wings', flapping them up and down in a movement akin to flying. They have shorter tails with a serrated spine and feed on clams and oysters, which are cracked by flat pavement-like teeth.

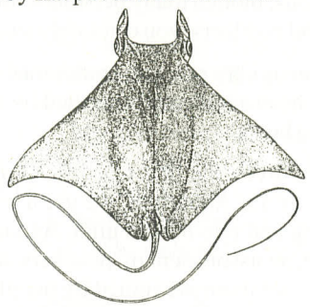


Fig.427 **Devil ray**

The devil ray or manta (*Mobula*) is a harmless fish which feeds on minute planktonic crustaceans and fish. It gets its sinister name from the two flexible, horn-like extensions on the head, which are used to funnel prey into the mouth. Mantas grow to 7·3 metres (body width) and seem to be fond of jumping out of the sea to land with a resounding splash that can be heard miles away. They do not have a spine on their tail.

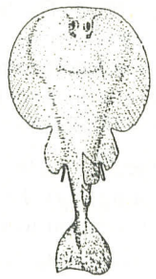


Fig.428 **Electric ray**

Electric rays or numb fish (*Narcine, Torpedo*), though related to sting rays, have a distinct fish-like tail and a flat, disc-like body. They can deliver an electric shock,

depending on their size, from 60 to 200 volts. But such powerful shocks of 170 to 220 volts are produced only by large electric rays growing to 1.8 metres. Most electric rays produce 75 to 80 volts or less. The lesser electric ray (*Narcine*) produces only 14 to 37 volts. The ancient Greeks and Romans knew this, and used them to treat gout and headaches! It is believed that the electrotherapy started when Emperor Tiberius accidentally trod on an electric ray while bathing at Capri and found that the shock benefited his gout.

He struck his blow with aim so sure,
But felt an impact like never before;
He thought he'd strike hard once again,
But pulled back fast as he reeled in pain.

Fair Queen, forebear to angle for the fish
Which being caught strikes him that takes it dead;
I mean the vile torpedo … Marlowe, *Edward III*

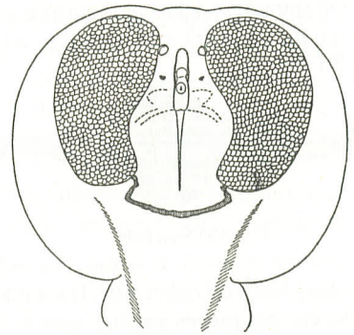


Fig.429 **Electric organs in an electric ray**

People are intrigued that a fish can produce electricity. They have electric organs composed of multiple stacks of coin-shaped cells called electroplaques. The electroplaques are derived from neuro-muscular tissue. Nervous stimulation to each of them produces a small electric flow, from one face of the coin-shaped cell towards the other. Many electroplaques are arranged in a column and, when stimulated simultaneously, produce a strong total current, like batteries aligned in series. The more electroplaques in a line, the greater the voltage produced and the more stacks aligned in parallel, the greater the amperage.

The ability of electroplaques to generate an electric current is due to the structure of their cell membranes and the activity of chemical pumps. Sodium ions are actively pumped out of the cell, creating an electro-chemical gradient across the cell membrane. When the resting permeability of the cell membrane is altered (initially by nervous stimulation of the electroplaque surface), there is a net flow inward of the positive sodium ions. The flow of these positive ions toward the negative interior sets up a small electric current.

When I was younger (and naughtier), I had a cocky colleague from Pune who refused to believe that a fish could give an electric shock. We had just caught an electric ray, and were keeping it in a tub prior to release into the display tank. Wearing my most

innocent expression I handed my colleague a metal-framed net and asked him to catch the fish. He bent down to net it, and I still remember his hasty reaction, both in words and action, as he leapt almost a foot in the air!

In all the above fishes, the males can be distinguished, as in sharks, by having claspers used for mating.

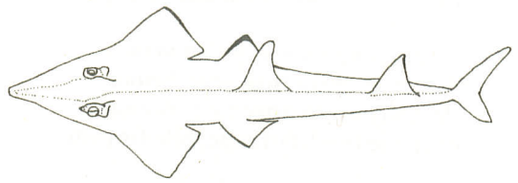


Fig.430 **Shovel nosed ray**

The shovel-nosed rays or guitar fish (*Rhynchobatus, Rhinobatos*) are halfway through their evolution from sharks to rays. The front of the body is flattened into a spade-like head and body, and eyes and spiracles on the upper surface and mouth, nostrils and gill-slits on the lower. But the tail is typically shark-like, with (two) distinct fins on the back and a tail fin. Larger ones grow to 2·1 metres.

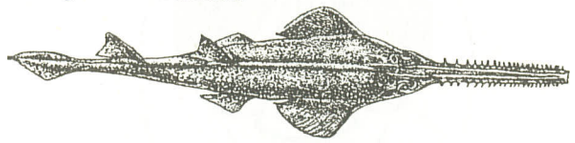


Fig.431 **Sawfish**

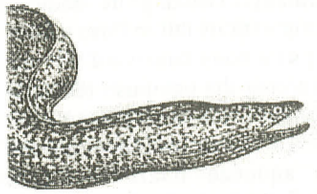
Finally, we have the sawfish (*Pristis*). It is aptly named; in front of the head is a long, flat snout with a row of sharp teeth on either side. It is said to rush into shoals of fish and, swaying from side to side, cut into pieces any fish near it. It slaughters as many as it can before the shoal escapes, then begins to eat. Large sawfish grow to 7·3 metres. And how does the mother give birth to young without getting hurt? Simple; the teeth on the baby's snout are folded back and sheathed.

From time immemorial, stories of sea monsters have captured our imagination, and hoaxsters have taken advantage of this. Some of these are curiously called Jenny Hanivers. Their first record is in a 1558 book *Historia Animalium* by Honrad Gesner, with a woodcut of a "basilisk"– a type of lizard regarded as the king of all serpents. Fake sea monsters were fashionable at that time, and he saw one in the shop of a vendor of quack medicine. Credit goes to him that he realised that it was a hoax made from a ray fish, and he published the woodcut with the express purpose of exposing the trick.

Fig.432 **A Jenny Haniver (From a wood-cut in Gesner's Historia Animalium, 1558)**

Jenny Hanivers are made from sting rays or guitar fish (shovel-nosed rays). The spinal cord and fins are cut in the centre to create legs and the spear-like tail of the monster. Its pectoral and pelvic fins, which are anatomically joined, are cut and separated to form the wings. The man-like face is actually the nostrils (which look like eyes) and mouth of the fish.

54 The Misunderstood Moray



The ancient rule, the good old plan
That those shall take who have the power,
And those shall keep who can.

Of the various fishes found near the shore in the tropics, especially in rocky areas, none commands more respect than the moray. Slimy, ugly, looking like a snake and swimming like one, and with a mouth full of needle-sharp teeth, it appears as ferocious as a cobra.

Fig.433 **A painted moray**

Morays belong to a branch of the eel family, comprising some 120 species. With a scaleless skin, without pectoral and pelvic fins, and with small rounded gill-openings, they vary from 15 cm to almost 3 m in length, though most are a little over a metre. Lurking in rock caves or crevices and tunnels in coral reefs, they are abundant in shallow water, rarely being found in the open sea or below 45 metres. During the day, they hide among the rocks, rarely venturing out of their holes, but you can see plenty of them at dusk, with their heads protruding out, seeming to be perpetually yawning. Actually they are breathing, alternately opening and closing their mouth. Usually dull in colour, some appear greenish because of the coating of yellow algae growing on the blue-gray skin.

Morays come out at night to feed. They have poor eyesight and hunt by smell, their most favoured prey being octopuses. But the latter, over thousands of years, have evolved a strategy to protect themselves. When attacked, they throw out a cloud of 'ink'. While this makes the water in the vicinity turbid, so that the octopus can slink away, the ink serves another purpose. It deadens the moray's sense of smell, so that it cannot locate the octopus.

I have often experimented with octopuses in the Aquarium. First I annoyed some octopuses in a bucket of sea water so that they released their ink. After emptying the bucket into a tank holding the morays, I released an octopus there. The morays would not react even if they accidentally bumped into the octopus.

Fig.434
A parrotfish inside its slimy "night gown"

Some parrotfish have evolved a similar strategy. Every evening, they secrete a "night gown" of slime around their body, with only a hole near the mouth for breathing, and go to sleep under this transparent blanket. This serves to prevent their body odour from seeping out into the water and attracting foraging morays to them. The blanket is broken up after the parrotfish wakes up, and a new one is made in the evening.

Some morays, like the snowflake moray (*Echidna nebulosa*), have blunt teeth and feed on lobsters, crabs and prawns.

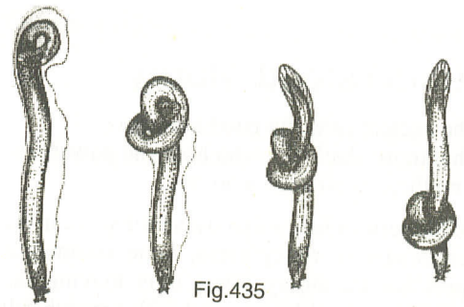


Fig.435

Morays, like hagfishes [above] and eels, can twist their flexible bodies into a knot and then move the knot forward to ward off a clinging octopus

Often, when a moray grasps a large octopus in its mouth, the latter fastens its arms around the moray's head, sticking fast with its suckers. The moray uses a strategy. Twisting its body, it makes a loop with its tail to form a knot. Now it slips its body backward through the loop, forcing the octopus's tentacles loose. If caught (by humans) when it has gorged itself, it will tie itself in a knot and then squeeze itself backward through the loop, forcing the eaten fish, one by one, out of its mouth. The same trick is used by a moray caught on a hook to break the line or pull the hook from its mouth.

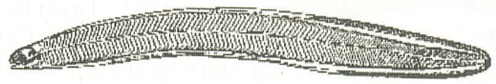


Fig.436 **Leprocephalus larva of a moray**

Not much is known about the breeding habits of morays; they have flat, ribbon-like, glassy transparent leptocephalus larvae just like their cousins, the eels. A leptocephalaus is little more than an elongated sack filled with a jelly-like tissue. It does not feed in the traditional sense; instead, it absorbs food from its skin. It also lacks gill filaments and takes up oxygen from the surrounding water through the skin. After reaching a certain stage, the teeth are resorbed, the teeth of the adult begin to form, and the adult head is formed. The gut becomes functional, and the circulatory system acquires red blood cells. The leptocephalus also shrinks, so that the juvenile is actually shorter.

During the Roman Empire, it was believed that morays tasted best if fattened on human flesh. A cruel Roman knight, Veddius Pollio, who was a friend of the Roman emperor Augustus (63 B.C. - 14 A.D.) was notorious for throwing disobedient slaves into his moray reservoir. At a dinner with Augustus as chief guest, a slave broke an expensive crystal goblet, whereupon Pollio ordered the slave to be thrown to the morays, exclaiming "Ad muraenas". Though the slave fell at his feet begging for mercy, Pollio did not relent. Whereupon Emperor Augustus intervened, dismissing the slave on imperial decree, and ordered all of Pollio's crystalware to be broken and his moray reservoir destroyed.

A wealthy Roman, Hircius, had a reservoir that could hold 6,000 morays; these were used in a banquet held in honour of Caesar's triumph. The moray eel reservoirs of another Roman statesman, Marcus Licinius Crassius (12 B.C.) were also well known.

Why are morays held so much in awe? While it normally minds its own business inside its hole, it does have a territorial instinct. If approached, a moray uses body language to warn the intruder. While it normally opens and closes its mouth rhythmically for breathing, a wide open mouth is an indication to keep off. If this is ignored, the moray will swim out of its hole, trying to chase the intruder away. And we misinterpret this as an act of aggression by the moray.

Though it be the song of old and young
That I should be to blame;
Theirs be the charge, that speaks so large

In hurting of my name.
The Nut Brown Maid

Most of the so-called unprovoked attacks by morays actually involve some kind of provocation. A person carelessly putting his hand in a hole to search and catch a lobster or crab finds it grasped by a moray. A current fashion among scuba divers is to show off their bravery (?) by feeding morays. A dead fish is held close to a rocky cave to entice a moray to come out. When it does, the diver moves the food farther away. When it swims speedily to dart at the food, an inexperienced diver loses his nerve, drops the food and jerks his hand away. The moray, with its poor eyesight, ignores the slowly falling food but is attracted by the fast moving hand. The smell of the food has aroused its hunger and it snaps at the diver's hand. And yet another moray has acquired an evil reputation!

An injured moray is, of course, another matter. Divers also show off by spearing a moray. Using the 'knot' trick, the moray can slide along the harpoon towards the diver's hand. And a moray caught on a hook can climb the angling line tail first and come aboard the boat. An injured moray thrashing about in a small boat is no laughing matter, although I have laughed heartily at the sight of three fully dressed men hastily jumping out of a boat because of such a moray, into the sea. I could afford to laugh because I was not inside the boat!

There are, however, a few stray instances of morays attacking without provocation. In 1902, Alcock aboard the Royal Indian Marine Survey Ship *Investigator* wrote of such an experience as follows: -

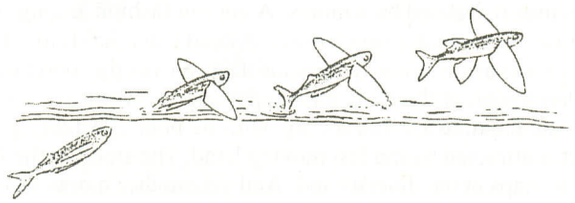
"As it was low spring tide, we had to leave our boat at the outermost edge of the Betrapar atoll and to wade across the reef to the island, and during this delicate progress– for growing coral is by no means pleasant stuff to walk upon, even when a man is shod– we were surprised to find ourselves furiously attacked by a swarm of the spotted reef-eel (*Muraena pseudothyrsoidea*), for it was their breeding season, a period when they are always strangely irritable and aggressive."

There are two misconceptions about morays. One is that its bite is venomous. It is not, but as the wound is not clean and has jagged, lacerated flesh hanging loose, it is advisable to bathe it with plenty of clean sea water and dab an antiseptic on it.

The second fallacy is that a moray has a "bulldog grip", and will grab and hold a diver tenaciously until he drowns. Nothing can be farther from the truth. A moray's bite is quick and brief, and it makes no effort to hold on. For its respiration, the moray has to constantly open and close its mouth like all fish, so it cannot hold its breath while clamped on to a diver's limb. In the absence of concrete evidence, it is like the tales of giant clams closing on divers' legs till they drown; perhaps possible, but unlikely and not authenticated.

Although moray flesh is tasty, there is one culinary hazard. The blood (uncooked) of all eels is poisonous and can sometimes even be fatal. Drinking eel blood results in nausea and vomiting, frothing at the mouth, bloodstained stools, distress while breathing and sometimes death. If a drop of eel blood gets into the eye, within minutes there will be reddening and a burning sensation. Later, a feeling of some foreign body in the eye develops and lasts for days. A drop of blood on the tongue makes it red and burn, with copious saliva as our body tries to dilute it and wash it away.

55 The Fish That Flies



I have the courage to scan the sky
With frail, half-opened wings,
To own the blue and taste the joy
The vast Infinity brings.

You will not find it in the fish market, nor will you see it while bathing in the shallow sea. It is a creature of the open sea in the tropics, far from land. The sight of a school of these, shooting out of the sea and, apparently defying gravity by skimming far above the waves, almost always raises the question: do flying fish actually fly? It would be more appropriate to name them as gliding fish. Flying fish do not flap their 'wings' (fins), although the vibrations of these fins as the fish encounter strong winds gives the illusion of beating of wings.

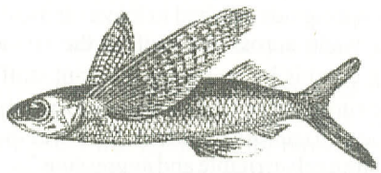


Fig.437 A "two-winged" flying fish (Exocoetus). (From British Museum Catalogue)

There are two kinds– though closely related– of flying fish. *Exocoetus* have only their pectoral (shoulder) fins enlarged to form wing-like structures, but in *Cypselurus* both the pectoral and the pelvic (or ventral) fins are elongated. In both types, the pectoral fins form the main lifting surface. Under water, these fins would act as brakes, so they are kept folded close to the body. The tail serves as a rudder during flight. The lower lobe of the tail fin is much longer than the upper one.

Cypselurus is larger than *Exocoetus*, growing to 45 cm. The size is, of course, limited by the amount of thrust they can produce in order to fly. A great deal of speed is required to overcome the friction of water and raise them out of the sea. A heavier body requires more power. *Cypselurus* can afford to grow a little larger than *Exocoetus* as it has the advantage of two pairs of "wings" to sustain the length of its flight, whereas *Exocoetus* has only one pair.

Flying fish are related to gars (*Strongylurus*) and half-beaks (*Rhynchorhamphus*). Both flying fish and half-beaks have a protruding lower jaw and elongated lower tail lobes, and the latter use them in a similar sculling motion to skip across the water for quite some distance.

When a flying fish wants to take off from the water, it swims just below the sea surface, with the upper lobe of the tail often projecting above the water. It turns upwards like an airplane on the airport runway just before being airborne, the fish beats its tail vigorously back and forth in a sculling motion and finally rises in the air. The four-winged flying fish (*Cypselurus*) will also open its pelvic fins. The duration of the flight is usually about 10 seconds, in which time the fish will cover 30 to 90 metres and reach a height of 1·5 metres above the sea surface. If, however, the wind is favourable, flights of 300 metres lasting 40 seconds, and to heights of 7·5 to almost 11 metres have been observed.

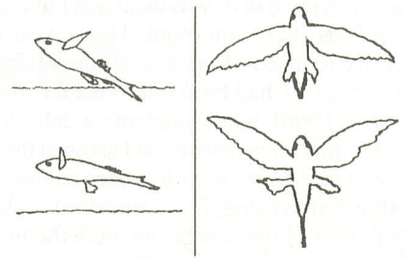


Fig.438

A flying fish in action. (Upper row): Rising from the water, from side (left) and from above (right). (Lower row): In full flight, from side (left) and from above (right). (From a sketch by Cromie)

Till, with a flutter of wings that churned
The shivering shoals to foam,
Flight after flight took air and turned
To find a safe home.

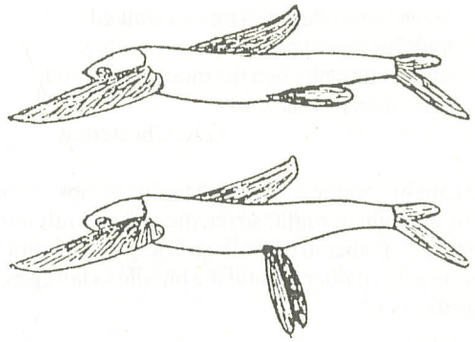


Fig.439

Position of fins in full flight (above) and before re-entering the water (below) (After Hankin)

At the end of the flight, the fish folds its fins and dives back into the sea. But often a fish, when its flying speed is lost, will lower its tail, begin to beat the water with it, thus regaining speed, and fly off again. The fish also fly, land and fly several times in succession. Ten such broken flights have been observed in 26 seconds. Many a time, after dropping in the water, the fish will take off in a different direction. They usually fly in a curved path, but they cannot change course in mid-air.

We do not know how well flying fish can see outside water, but in daylight they seldom hit a boat or ship. They may glide straight at a ship, but suddenly plunge into the sea, and twist backward to swim at a tangent and then take off in the opposite direction. At night they are definitely attracted towards lights, flying to their doom to land on the

Fishermen place a light bulb just below the sea surface and catch as many as three dozen flying fish in 90 minutes.

I remember one night on the equator when I was on the night shift. To while away the time, I was seated under a lamp, reading a book. Suddenly I was hit on the chest by something hurtling at me. While I was recovering my breath, I heard some flapping and, shining a torch, saw a flying fish. It was dead and I did not have a specimen for our collection at Mumbai, so I spread its fins, pinned them so as to hold them stretched out and preserved it. When we touched Mombasa, all the scientists and most of the crew made straight for the town, as we had been out at sea for over a month. Only the chief scientist and I remained on board, when suddenly a delegation of locals came on the ship. I took them to be local marine scientists, so I showed them the flying fish. Cameras clicked away and there was also a person with a video camera who was enthralled by the fish. At dinner on the ship that evening, I was surprised to see myself on the television screen in the mess room. Part of the delegation were the local TV crew and, with the flying fish, I too was the cynosure and envy of all eyes.

Flying fish feed on small fish and crustaceans in the water. They lay their eggs on floating clumps of seaweed or surface debris. Some species make a crude nest by wrapping tightly packed balls of seaweed with strands of some white, elastic material. The eggs are attached to one another and to the weeds by thin silky threads. They are heavier than water and would sink if not attached to floating objects. Newly hatched young look like the round floats of sargassum weed.

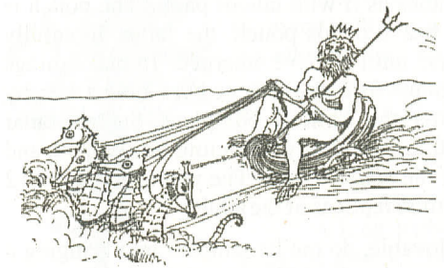
When fishes flew and forests walked
And figs grew upon thorn,
Some moment when the moon was blood,
Then surely I was born.
G.K. Chesterton

Flying fish are caught commercially by hanging lamps on the mast of sailboats. The fish are attracted to the light at night, strike the sail and fall into the boat. In India, natives tie bundles of sticks together in a bunch and drag this behind their boat at the end of a long line (cord). Flying fish gather around the bundle to lay eggs, when the bundle is gently pulled over large dip-nets.

Why do flying fish fly? After all, very few fishes have evolved this habit. Two or three types of fresh water fish– the hatchet fish (*Gasteropelecus, Carnegiella*) of South America can "fly". These small (3 to 6 cm) fish are flat and have an arched belly to support the powerful pectoral muscles, but the flight is only for a few centimetres. The flying gurnard or sea robin (*Dactylopterus volitans*) is larger (50 cm), is found in the Mediterranean Sea and is able to 'fly' through the water using its brightly coloured pectoral fins.

Coming back to flying fish– flight for the purpose of feeding or mating is ruled out. And it is certainly not *joie de vivre* (the joy of living) which makes for the seemingly exuberant flights. The most plausible reason is to escape the attention of the dolphin fish (*Coryphaena hippurus*); it should not be confused with dolphins, which are mammals. Dolphin fish feed extensively on flying fish, and as the latter's speed in the air is more than its swimming speed in the water, it has a sporting chance of escape.

56 Women's Lib in the Water



Though the sea-horse in the ocean
Owns no dear domestic cave;
Yet he slumbers by the motion
Rocked of many a gentle wave.
Song for the wandering Jew
William Wordsworth

When the seawater near shore has been diluted by the rain, is the time to look for sea horses. If you search carefully in places where there is a profuse growth of seaweeds or sea grass, sea fans, sea whips and hydroids, you are likely to find some. It would require a considerable stretching of the imagination to call a sea horse a fish. But it is one, despite the lack of scales or a forked tail or the typical fish's mode of swimming. Nothing about the sea horse seems to be ordinary. Mother Nature seems to have created this animal during a fit of absent-mindedness, for she has endowed it with the head and neck of a horse (or, more accurately, the knight in chess), a body encased in armour, a tail like a monkey's and a pouch like the kangaroo's.

Fig.440
A sea horse resting with its tail curled around a seaweed

The sea horse swims, slowly and in a dignified manner, as if it had all the time in the world to go places. But how does it swim? If you look carefully, you will see a small transparent fin on its back, quivering rapidly. This fin vibrates at an incredible 35 times a second, and it is this miniature dynamo that propels the sea horse forward. As it swims, it maintains its balance with the help of a pair of tiny, transparent fins near the gill-opening.

Its body is encased in interlocking bony plates which form a series of about 45 rings. The tail, however, can be coiled as by a chameleon, and is used, when the sea horse wants to rest, to grasp and hang on to seaweeds or sea fans. This curious creature shares another common feature with the chameleon; each eye can move independently in different directions. It is a weird sight to see a sea horse peering one way with its left eye and quite another with its right.

Sea horses also make loud clicks– singly or in a series of two to five every second. Although they normally hold their heads at right angles to their bodies, just before clicking a sea horse lifts its head several times and then holds it so that the top is almost straight in line with its back. There is a "coronet"– a star-shaped bony crest at the back of the head. When the sea horse lifts its head suddenly, the edge of its skull slips under the coronet and, as it lowers its head, the edge snaps out. The vibrations set up by this snapping are transferred to and amplified by the fish's air bladder.

As if all these characteristics were not quaint enough, it is the father who gives birth to the young! The male seahorse has a pouch on its belly. During courtship, a couple lock tails together. Then one of them begins to tremble rapidly, this stops abruptly, and this is a signal for its partner to begin trembling. This continues for about half an hour and ends in an embrace, during which the female transfers her eggs– and her responsibilities– to the male's pouch. A couple may embrace as many as a dozen times, at intervals of five minutes, before all the eggs are transferred. Many females may visit a

male, until its pouch is full. The eggs remain in the pouch for a month to 50 days, at the end of which about 200 babies are born of the father.

Fig.441 **A male sea horse giving birth to young from its distended abdominal pouch**

The delivery is slow, extending for two or three days. The father turns pale, and twists and writhes as if with labour pains. The pouch is now fully distended. With a heave of his pouch, the father forcefully expels 10 to 30 babies at a time, until all have emerged. To make things easier, he rubs his pouch against any convenient hard object nearby (rocks, shells, etc.) Even after the birth is complete, the muscular contractions of the pouch continue, gradually becoming less violent, and finally the slit-like opening of the pouch closes. The young are about 12 mm long at birth, and are miniature replicas of the adult.

Although they are so lovable, do not be tempted into bringing a sea horse home. They eat only moving food. The mouth is a long, narrow tube, with no teeth. The food has therefore to be small enough to pass through it. In nature, small shrimp-like animals and side-swimmers (Amphipods) are taken. In captivity, adult brine shrimp (*Artemia salina*), which are found in salt pans, or mosquito larvae or juvenile male guppies (a particularly small fish) can be given, but they must be alive and moving. If you listen carefully when a sea horse is feeding, you will hear faint clicking sounds. (These sounds are also made during courtship.)

As sea horses rely mainly on concealment to escape their enemies (sting rays, skates and fishes living on the sea bottom), they do not grow to a large size. The larger of the two species found in our seas is said to grow to 30 cm, but we usually see them only half this length. The large ones probably live in deeper water, down to a depth of 70 m.

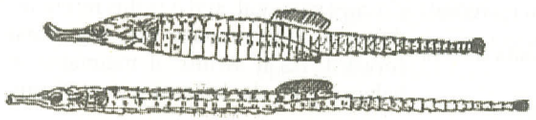


Fig.442 **Two kinds of pipefish**

In the pipe fishes, which are cousins of the sea horse, the body is shaped like a long, straight tube, with a transparent tail fin at the tip. Unlike in sea horses, the head of pipe fishes is not bent at right angles to the body. They too live at the sea bottom among seaweeds, and because they are so thin, are even harder to locate than are sea horses.

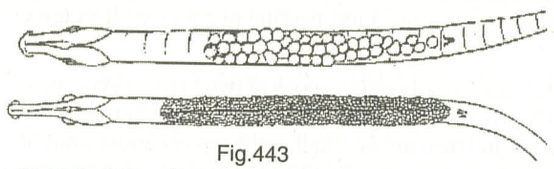


Fig.443
Male pipefishes with eggs between the abdominal folds

Here, too, the father carries the eggs through to delivery, but instead of a pouch, two long parallel folds of skin hold the eggs. Most pipe fishes are marine, and our Indian species grow to 20 cm. But some pipe fishes have migrated successfully to fresh water. A common Indian freshwater species is found in the Ulhas river near Titwala, on the outskirts of Mumbai.

Our seahorse (*Hippocampus kuda*) grows to 30.5 cm, but the largest seahorse is found in the Pacific. Called *Hippocampus ingens*, it grows to 35.6 cm. The smallest is the pygmy or dwarf seahorse (*H. zosterae*) of Florida, which is only 5 cm when fully grown.

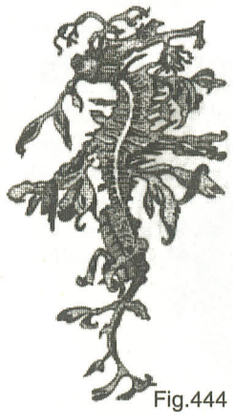


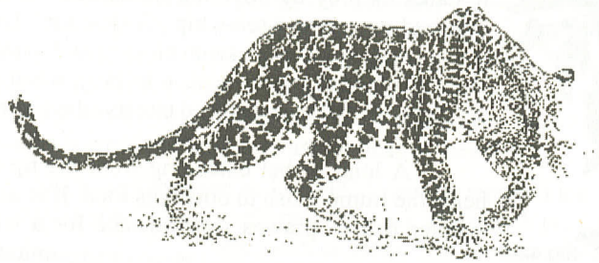
Fig.444
The leafy sea dragon *Phycodorus eques* from Australia is a sea horse with its exaggerated frills, looking like fronds of seaweeds, serving as an ideal camouflage to hide among seaweeds

Closely related to the true seahorses are the sea dragons of Australian seas, which grow to over 48 cm.

Giant cousins of pipe fish are trumpet fish (*Aulostomus*). Growing to 90 cm, it has a long, slender body. In spite of its size, it stalks its prey by hovering motionless vertically next to a seaweed, sponge or a sea-whip (*Gorgonium*). If no other shelter is available, it will even swim close to and parallel to any other slender fish until it gets close to its prey, when it makes a short dart forward and sucks its food into its tube-like mouth.

A long barbel extending from the tip of its chin also helps the trumpet fish to obtain its food. It is used as a lure that smaller fish or prawns may mistake for a worm. When the unlucky fish picks at the barbel, the trumpet fish sucks it in and swallows it.

57 The Leopard That Changes Its Spots



Oh, what a sight were man if his attires
Did alter with his mind;
And, like a dolphin's skin, his clothes combined
With his desires!

They say that a leopard never changes its spots, but some fishes do. And probably the most confusing (to us) of fishes is the dolphin-fish. People have generally heard of (and seen on the screen) the dolphin, which is a cute, friendly and intelligent mammal which performs tricks in oceanariums and entertains us. But hardly anyone, except fishermen and marine scientists, would have seen a dolphin-fish. Yet it has a cosmopolitan distribution in tropic seas, preferring water of over 24° C. There are two species– the common dolphin-fish (*Coryphaena hippurus*) growing to 34 kg, and the smaller pampano dolphin-fish (*Coryphaena equiselis*, different from the pampano, which is a fish resembling the pomfret). Both look similar, with the same colour pattern, so that it is difficult to tell them apart.

Dolphin-fish are active swimmers, having a large gill-area compared to their body weight. This is necessary to sustain fast swimming over long periods of time, and to flee from their enemies– tuna, marlin, sharks and larger dolphin-fish. They feed on flying fish, squid, prawns and crabs and the young of sailfish (*Istiophorus*). The last item in the dolphin-fish's diet is a great help to scientists studying sailfish, as it saves them from the tedious chore of towing slow-moving, fine-meshed nets in the sea, frequently with no luck, for catching the tiny baby sailfish. The sailfish may be around, but they can easily avoid the slow nets and escape being caught. From the size (i.e., age) of the young sailfish, scientists can estimate their breeding season.

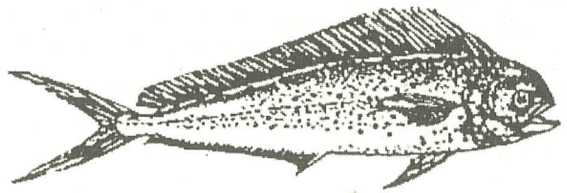


Fig.445 **Dolphin fish (*Coryphaena hippurus*)**

Dolphin-fish have a long, paddle-shaped body with a long dorsal fin that extends from the head to near the tail. But it is the fish's colouration that has enthralled people. During life, the fish displays variegated iridescent tones of blue, yellow and green. The upper part of the body has a blue tone with dark spots, while the lower portion has a yellow shade with jet black spots. Crystals in the skin reflect light and highlight the colours. But it is the change of colours as the fish is dying that has fascinated people. Wave after wave of different colours pass over the skin, like a living prism until the fish is dead. Thus, within minutes of capture, the spectacular ocean blue colour disappears, to be replaced by a kaleidoscope of different colours ending with yellow and silver.

Its colours changing, as from clouds and sun
Shades after shades upon the surface run;
Embrown'd and sombre now, and now serene,
In limpid blue and evanescent green.

The fish is an angler's delight because of its fighting qualities when hooked. It takes the bait with a sudden rush. Anglers also take advantage of a weakness of the fish; when one is hooked, the other members of its shoal will hover around. The angler leaves the hooked fish as a decoy behind the boat and catches many more. It is also excellent eating. Earlier there was a custom to put something made of silver in the pot in which dolphin-fish were cooked. If the flesh was poisonous, the silver should turn black.

The habit of the dolphin-fish to take refuge under floating seaweeds is also used to catch it. In earlier times, bundles of reeds were made and a rock tied below the bundle as ballast. This primitive raft was allowed to float about until dolphin-fish gathered below the reeds, when the fishermen would cast their lines and catch them. Even today, the Japanese use anchored bamboo rafts to attract the fish. A lure held on a pole is passed across the current upstream of the raft. After a shoal of dolphin-fish gets attracted, a purse-seine is spread around the shoal to catch them. Or the purse-seine may be set around the raft, which is then pushed out of the centre of the net. The fishermen find that dolphin-fish below a raft are bigger than those under clumps of sargassum seaweed. The fish stay overnight under the raft, but at daytime the position of the fish depends more on the current than the shadow below the raft.

In East Africa, where the dolphin-fish is called dorade, the northern monsoon from November to April causes sargassum weed to gather off the coast. These fish accumulate there in large numbers and are caught by commercial fishermen. In Hawaii, the fish is called 'mahimahi'.

People are often intrigued as to why this fish was named dolphin when a mammal of the same name exists. This name is used only by English-speaking people, and the reason for this can only be inferred. Perhaps early English explorers in unfamiliar tropical seas were confused by the behavioural similarities of the two; both tend to school, leap out of the water and swim at the surface with their head breaking the water's surface. On the other hand, these explorers often gave common names to plants and animals for no better reason than that it reminded them of something with which they were familiar. They were desperately trying to create some order out of their encounters with entirely new fauna and flora, and did not realise the confusion that might arise at a later date.

58 William Tells in the Water

And when we hear it with our ears, we marvel therein
For therein be strange and wondrous works ...
Ecclesiasticus

William Tell of Switzerland was a legendary archer in the 13th century. The Austrian bailiff Gessler had heard of Tell's prowess with bow and arrow. To test his skill, so the story goes, Gessler placed an apple on the head of Tell's son and asked Tell to shoot at the apple. The apple was cleanly pierced by Tell's arrow without touching even a hair on his son's head.

We have equally skilful marksmen in the water but, instead of arrows, they shoot "bullets" of water to hunt their prey. There are six species of "archerfish" living in tropical estuaries that do this, the commonest being *Toxotes jaculator*. They can also tolerate fresh water, and often migrate upstream from their estuarine haunts.

Fig.446 **Archerfish shooting down an insect**

Though well known to natives, archer fish first came to the notice of Mr. Hommel in Batavia (Indonesia) in 1764, who wrote a letter to Dr. John Abert Schlosser, a zoologist in Amsterdam (Holland) describing the antics of the fish. He wrote of a fish that frequents river banks which, when it spots a fly or some insect sitting on an overhanging branch, swims to a distance of up to two metres and ejects drops of water from its mouth which invariably strike the insect, making it drop into the water where it is eaten by the fish.

This habit seemed so ludicrous and unlikely that his description was ridiculed as a cock-and-bull story. Hommel added to the confusion by sending a wrong specimen to Europe, so that the Russian zoologist Pallas placed it among the drumfish family. But in 1902, another Russian ichthyologist named Zolotnisky proved that Hommel was right in his description of the fish's quaint habit, which was further studied by Dr. Smith.

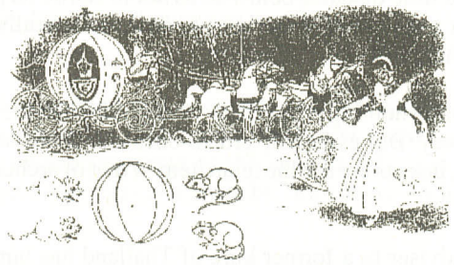
The propulsion mechanism of the water "bullets" is a groove running lengthwise along the roof of the fish's mouth and widening into a funnel-like opening at its rear end. When the tongue is pressed onto the groove a tube is formed. By compressing its gill covers, water is forced into this tube, but is kept from shooting out by the paper-thin flexible tip of the tongue which acts as a valve. By lowering the tip of the tongue a drop of water is ejected with force. By manipulating its tongue, the fish can eject a series of drops in rapid succession.

The fish's aim is unerringly accurate. It can even judge the refraction of light between air and water which makes the insect appear at a different position from where it actually is. This error is reduced by the fish positioning itself almost vertically below the insect. If the water is turbid the fish comes to the surface of the water. But if the water is clear, it remains a little distance below so as not to startle its prey. Its eyes are highly mobile and as with a sea horse, it can see up, down or laterally, giving the fish a very intelligent appearance.

Its babies start shooting when quite young, although they can shoot only up to a few centimetres away. But even half grown ones can shoot up to almost two metres away. Surprisingly, insects are not the main item of diet of archer fish; it prefers shrimps or aquatic worms.

A fishery adviser to a former king of Thailand has humorously written in his anecdotes how he was often amused, at the expense of his annoyed guests when their lit-up cigarettes were extinguished by archer fishes kept in a nearby tank, shooting water drops at the cigarettes shining in the darkness of the night!

59 Cinderellas of the Sea



A world of wonders, where Creation seems
No more the works of Nature but her dreams!

As schoolchildren, we were fascinated by the tale of Cinderella, whose fairy godmother, with a touch of her magic wand, changed her ragged dress into one of bejewelled splendour. An equally miraculous change of "dress" takes place in the marine angelfishes (subfamily Pomacanthinae). .

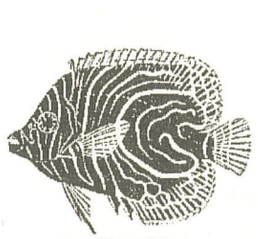


Fig.447
A typical juvenile angelfish

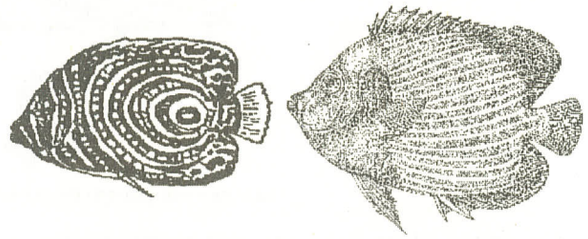


Fig.448 **Juvenile (left) & Adult (right) Emperor angelfish**

There are many species of angelfish in the Atlantic, Pacific and Indian Oceans, but surprisingly, the young of all of them are confusingly alike. All start life as dark blue fishes with a few vertical white stripes. (A few Atlantic species have yellow stripes.) As they grow, the number of stripes increases and their configuration also changes. Soon, light blue stripes appear between the white ones. Thereafter, as the fish grows this colour pattern disappears, to be replaced by completely different colour patterns, which are different in the various species.

We have three species of angelfish in Indian seas. The Emperor Angelfish, *Pomacanthodes imperator*, is probably the prettiest, as you can see in the accompanying picture. It is also the smallest of the three, growing to 20 cm. In the young, the stripes are highly curved into incomplete hoops, at the centre of which is a white ring. India's leading fish expert, Francis Day, mistook the young for a different fish, and named it *Holacanthus nicobariensis*. He could not imagine that it was the young of the purplish-blue adult with its 20 to 25 horizontal stripes, a black patch on the chest and throat and a violet-black band across the eyes which gives it the appearance of a masked bandit. The Koran Angelfish, *Pomacanthodes semicirculatus*, is aptly named.

While the tail in the young of the other two species is transucent, here it displays a series of white bars on a blue background. In a few specimens, these vaguely resemble the Arabic words "Shan-e-Allah", meaning "Glory of God". The stripes in the young are not so curved, being only arched. The adult is not prettily coloured, but grows to a whopping 38 cm.

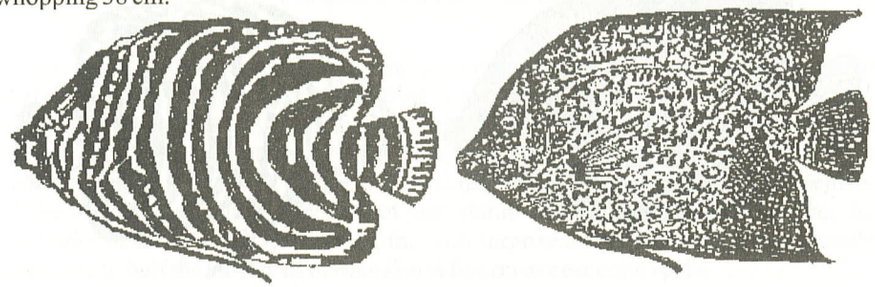


Fig.449 **Juvenile (left) and adult (right) of Koran fish**

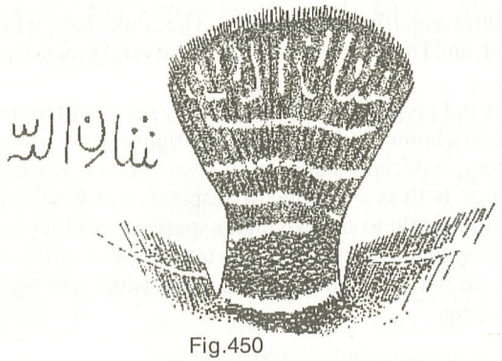


Fig.450
The Arabic words "Shan-e-Allah" as they are written (left) and as they appear on the tails of some Koran fish

Why are the colours of juvenile and adult so different? The adults feed mainly on sponges and sea-squirts (tunicates), though they may also take in sea fans, sea mats (Polyozoa) and hydroids. Little is known about the food of juvenile angelfish in our seas, but some juveniles of Caribbean angelfish are known to pick up parasites from the body of other species of fish. The conspicuous yellow stripes on the bodies of such "cleaners" are said to draw the attention of fishes wanting to be cleaned.

Though angelfishes are considered to be coral reef dwellers, Mumbai boasts of one species, the Blue-ring Angelfish, *Pomacanthodes annularis*. It might surprise you, but once just once I came across a live brain coral at Cuffe Parade (before it was reclaimed), and we do see bits and pieces of coral on Mumbai's shores.

While the colouration of the adult and young of the Emperor and Koran angelfishes were known to scientists, I had the pleasure to be the first to correctly identify the young of the Blue-ring Angelfish. It was a chance discovery; I got a specimen in a state of transition, so that it had the vertical, slightly arched, white stripes of the juvenile as well as the electric blue curved bands of the adult, on a body which was mostly bronze coloured (adult colour), but still retained its earlier navy blue at the periphery.

The famous ichthyologists Ruppell, Bleeker, Gunther and Day were not so fortunate, and all of them mistook the young for a different fish, which they called *Holacanthus striatus*. The adult grows to 35 cm.

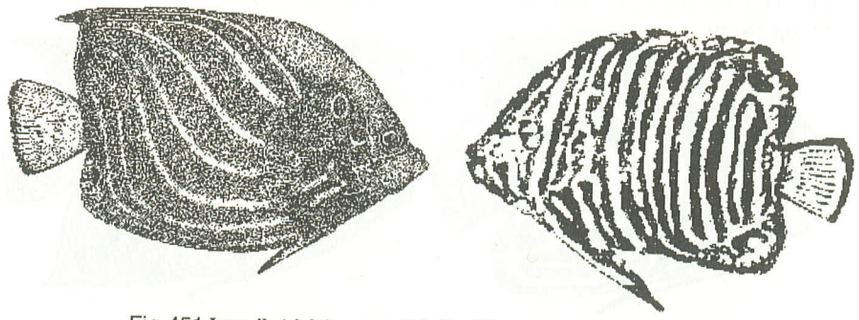


Fig.451 **Juvenile (right) and adult (left) of Blue-ring angelfish.**

When handling angelfishes, be careful. The adults have a long dagger-like spine under the gill-cover, and I have cut my hand badly several times while catching them.

Angelfishes are not gregarious, and we usually see a solitary individual, or a mated pair. The male selects a home, and will chase and fight off any fish venturing into what it considers its territory, especially males of its own species. The bright colour serves to advertise its presence, both as a warning to trespassers as well as to attract conspecific females. It is a thrilling sight to see two males sparring, circling each other like boxers, fins quivering, lashing their tails and trying to tear off pieces of skin from the adversary. Usually, however, no harm is done, and the vanquished fish signals its surrender by turning pale and fleeing.

Since the colours in the two sexes are alike, how do they tell each other apart? A male defending its territory will rush towards any fish of its own species with hostile intent. If the intruder is a male, it will either fight or flee. However, a female will respond differently, by subtle signals such as a quivering of her body or a clamping of the fins.

As with most fishes, angelfish lay a prodigious number of tiny (0·7 to 0·9 mm) eggs. On any given day, a female may release 25,000 to 75,000 eggs; over the entire course of its spawning cycle, up to 10 million eggs may be shed. Of course, a vast majority of these will be eaten by predators; three to four weeks after hatching, when the young fish (15 to 20 mm long) settle to the bottom, only a few will have survived.

60 Rainbows in the Sea

"Full many a gem of purest ray serene
The dark unfathom'd caves of ocean bear…"
Thomas Gray

Ask a nature lover which are the prettiest and most colourful creatures on earth and chances are that the reply will be birds and butterflies. Accustomed as we are to the sight of slimy, slippery grey fishes staring at us goggle eyed from a fisherwoman's basket, most of us cannot imagine that fishes too can be pretty. Yet the vast majority of fishes living on and among coral reefs are considered to be the most colourful denizens of the watery world. And they are not just dumb beauties without intelligence; their strategies of survival can leave us gaping with surprise and admiration. Also remember that close to half the variety of marine fishes live on or near coral reefs.

And where can we see these beauties? They are found, apart from the Lakshdweep and Andaman and Nicobar Islands, in the Gulf of Mannar that separates the Rameshwaram- Tuticorin coast from Sri Lanka. Some coral fish also dwell in Okha and Pirotan in the Gulf of Kutch.

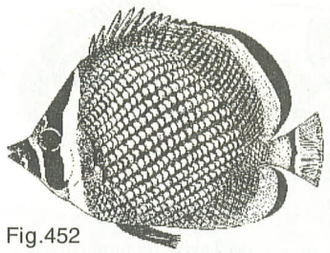


Fig.452
Collared butterflyfish *Chaetodon collare*

Why are coral reef fish so gorgeously coloured? Scientists earlier believed that they match the bright hues of live corals, blending with their background. But there is more to it than just camouflage. Birds occupy a certain territory and defend it against rival birds by song and posture. The "flag" or "poster" colouration of reef fishes similarly serves to advertise to rivals their dominance in the chosen area. Scuffles occur between rivals of equal size and strength, but these are rarely in the form of serious aggression, being rather ritualised showing off.

According to Hawaiian mythology their God Kummukona called all the fishes together, and to distinguish one from the other, painted them differently. He coloured some white and others yellow. He painted some with stripes while to others he gave just a mottled appearance by sprinkling their bodies with ash.

And how have these coral reef fishes spread over vast stretches of the Indian and Pacific Oceans? Most fishes living in coral reefs lay their eggs there. The eggs generally hatch after 24 hours. The young fish larvae leave the reef and spend weeks and sometimes months, drifting in the open ocean before settling over another reef which may be hundreds of kilometres away. This is how reef fishes get distributed over vast stretches.

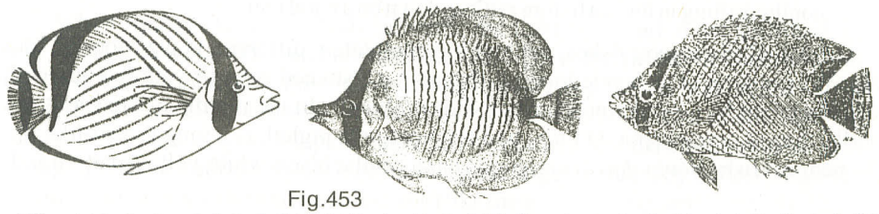


Fig.453
Different striped patterns in butterfly fishes: (a) Vagabond butterflyfish *Chaetodon vagabundus* (b) wriggly lined butterfly fish *Anisochaetodon Oxychaetodon lineolatus* (c) Chevroned butterflyfish *Megaprotodon stringangulus*

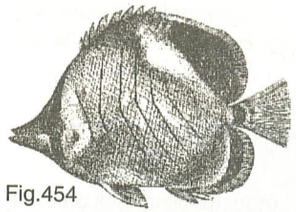


Fig.454
Saddled butterflyfish *Chaetodon Rhabdoporus xanthocephalus*

Some of the most prettily coloured coral-reef denizens are the butterfly fish. Like butterflies flitting from flower to flower, these fish go from one coral head to another, feeding on the coral.

Most of the ten varieties of butterfly fish in our seas have a yellowish brown colour, although their sole representative in Mumbai (*Chaetodon collare*) has a brownish body with a cherry red tail. As with all butterfly fish, its eyes are covered by a vertical black stripe running over them. The head is the most vital part of an animal, as it contains the brain. A predator invariable targets its prey's head. And the round glistening eyes of a fish are its most conspicuous part, hence the need to conceal them. All butterfly fish do this successfully.

Some butterfly fishes, like *Chaetodon auriga, C. lunula* carry this strategy of hoodwinking the enemy still further. While their eyes are hidden by the vertical stripe, they also display a conspicuous black spot, called eye-spot, at the rear end of the body near the tail. From a distance, the enemy is fooled into believing that the eye-spot is an eye, and attacks the tail end, which does not have any vital organs.

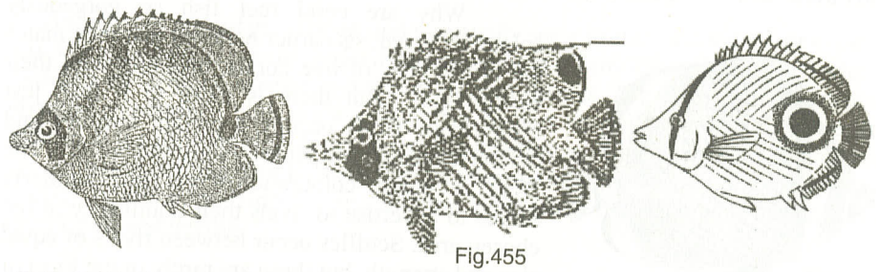


Fig.455
Butterflyfish with eye-spots: (a) Racoon butterflyfish *Chaetodon lunula,* (b) Threadfin butterflyfish *Chaetodon auriga,* (c) Teardrop butterflyfish *Chaetodon unimaculatus* [not Indian]

You may wonder why the two series of parallel stripes meeting at right angles on the body are there. A butterfly fish's body is flat and they swim together in shoals. Hence a fish in a shoal sees a fish in front only as a flat figure, without any ornamentation. To avoid mixing up of two different kinds of butterfly fish over a reef when their shoals accidentally meet, a butterfly fish will see the patterns on its neighbours bodies and avoid getting separated from its brethren. Butterfly fish are usually found in pairs. As one follows the other from coral to coral, the body can hardly be seen. If they become separated, one of them will swim up above the corals and tilt its body so as to flash the eye spot and parallel lines.

Butterfly fish are highly fecund; a female can lay upto 20,000 transparent eggs, each less than a millimeter in diameter. The eggs float up, and the young hatch in 28 hours. They are silvery and are protected by transparent, thin bony plates on the body. They may spend many months drifting in the sea before settling down on a coral reef.

Allied to surgeon fishes, yet looking completely different, is the Moorish Idol (*Zanclus cornutus*). A comic looking fish with a flattened sulphur yellow body with coal black bands, it swims in shoals on the coral reef. In the middle of the snout is a saddle shaped orange spot. On top, like a schoolgirl's pigtail, is a long thread-like fin. The pennant fish (*Heniochus acuminatus*) has a similar black-white-yellow pattern and

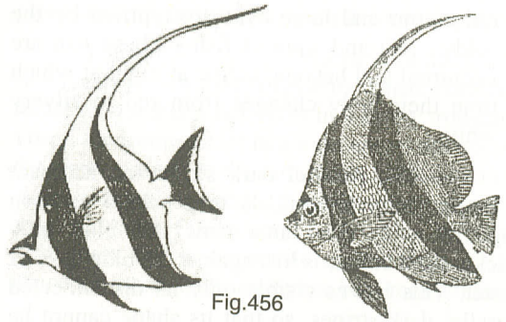


Fig.456
Moorish Idol (*Zanculus cornutus)* and Pennant fish (*Heniochus acuminatus)*

long fin, but is allied to butterfly fishes. The curve of its stripes makes it look as if a chunk of its body at the back has been bitten off.

Wrasses give a headache to people who classify fish. During their growth, their colour pattern keeps changing, so there are two male colour patterns and many intermediate phases. They have prominent front teeth like a rabbit's which are used to pull away snails clinging to rocks and to crack hard-shelled prey like crabs, sea urchins, brittle stars and worms. They are cousins of parrot fish, and some grow as big as 2.5 metres. Many bury themselves in sand at night before going to sleep. Others make their own "nightgown" every evening, by exuding a copious secretion of slime to cover their body in a cosy translucent blanket. They sleep securely within it. Their main enemies, moray eels, hunt by smell as their eyesight is poor. When the morays come out at night, in search of wrasses, the nightgowns prevent the wrasses' body odour from attracting the morays. It's just a different kind of deodorant from what human beings use!

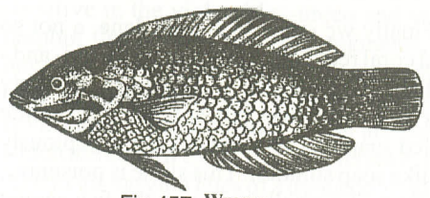


Fig.457 **Wrasse**

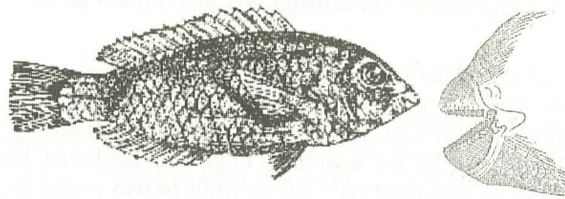


Fig.458 **Parrot fish** Fig.459 **Jaws of parrot fish**

Parrot fish scrape algae and break off pieces of live coral with their strong teeth, which are fused together to form a parrot-like beak. The coral is then ground into powder by two flat tooth plates in the throat. This is done to extract the zooxanthellae, tiny algae growing within the tissues of the coral. These are digested and the calcareous coral skeleton is voided in the form of white coral sand. At night some of them secrete a "blanket" of slime around themselves, leaving an opening in front for breathing. They go to sleep inside this cocoon, secure in the knowledge that this will block their body odour from going out into the water, and prevent detection by predators like moray eels, which hunt by smell. The "blanket" is thrown away in the morning. Many parrot fish start life as females and later change sex to become males. Others start life as males but with female colour patterns; they are known as primary males.

When sunlight falls on a body of water, the light rays tend to get absorbed, as they penetrate the water. The red component of daylight is the first to be absorbed and removed so that a little below the sea everything appears tinged with blue. A red object at this depth will appear black to us. Animals living in this twilight zone of dim light are usually red, because they will appear black and merge with the dark background, thus escaping a predator's notice. And their eyes are quite large, so that they collect whatever light still exists at this depth and be able to see (like the eyes of a nocturnal animal). The

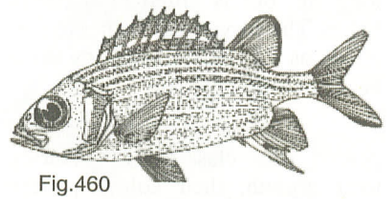


Fig.460
Squirrel fish (*Halocentrus rubrum)*

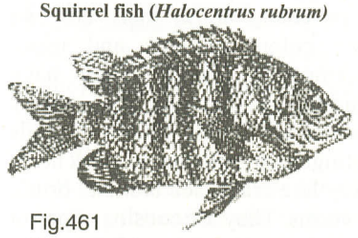


Fig.461
Sergeant major (*Abdudefduf saxatilis)*

red colour and large eyes are typified by the soldier fish and squirrel fish. These fish are nocturnal and become active at night at which time their belly changes from red to silvery white.

The parallel dark stripes on sergeant majors help individuals in a school to keep together. At the same time the blue grey background colour is lost against the blue haze of water. This leaves visible only its disconnected parallel dark stripes, so that its shape cannot be distinguished by an enemy.

Finally we come to a plain Jane, a not so colourful coral reef fish. Aptly named thread- and - needle fish, (*Grammistes sexlineatus*), its body looks as if a tailor has put stitches with white thread on a piece of black cloth. It is also called soap fish, as it exudes slime copiously when it is disturbed, making the water frothy like soap solution. This slime is poisonous and keeps its enemies at bay. But, in the confines of a small container, the fish cannot swim away and dies by its own otherwise effective means of defence.

Whenever I see these coral reef fishes, I am reminded of a very unusual lunch in Sri Lanka. I was already a proficient Scuba diver then, but I went there to learn the technique of catching these fishes alive, without hurting or harming them. My mentor was Rodney Jonklaas, a renowned exporter of coral fishes. He had a great sense of humour.

He gave his assistant divers a holiday for the day, and the two of us went in a small boat to the fishing grounds. Three hours of arduous fish catching and we were ravenously hungry, so we scrambled onto the boat, where he offered me a small sausage shaped loaf of bread. I waited for him to offer me something to go with the bread. He teased me, "Aren't you hungry? Then go ahead and eat!" All the while he was eyeing me intently, so I resigned myself to eat just bread and nothing else, and reluctantly bit into the bread. At my first bite, he burst out laughing; there was a delicious fried, filleted sardine embedded inside the loaf! It was a kind of closed sandwich. It turned out that Rodney had a neighbour who was a baker, and whenever Rodney caught fish, he gave some to him. In return, the baker gave him those special fish-enclosed loaves, of bread for picnics.

Most animals cannot see colour; their vision is restricted to black, various shades of grey, and white. If this is true for fishes, can the rainbow hues of coral reef fishes be visible to their kin?

The retina of the eye has rods and cones. The cones contain pigments that allow discrimination of colours, but this is possible only in bright light. In dim light, the rods come into play, detecting variations of light intensity, seen as various shades of grey. Thus those fishes whose eyes contain both rods and cones can see some colouration.

Pigments of the retina absorb visible light photons. The energies of the photons correspond to colour bands or wavelengths ranging from 400 nanometres (nm) at the violet end of the visible light spectrum to 700 nm for red. Maximum absorption takes

place at a well defined wavelength for each pigment.

The number of pigments varies among fishes, but to be capable of colour vision a fish needs two or more pigments whose absorbance spectra overlap. The number may relate to whether a fish lives in a sunny tropical, cloudy temperate, or dim deep-water visual environment. When light enters the ocean, red usually gets absorbed quickly in the upper waters. At the same time, blue scatters in all directions as it collides with water molecules and suspended particles and part of the blue goes back to the surface. In clear tropical waters (as on coral reefs), blue light penetrates to depths of about 66 metres (250 feet), but in temperate coastal waters filled with suspended matter, blue gets absorbed more easily, and green becomes dominant.

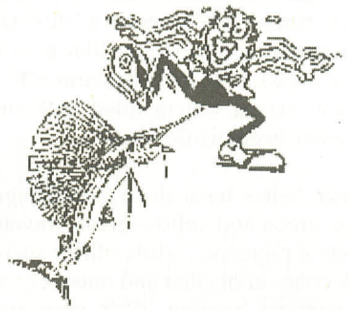
Some shallow water fishes have three visual pigments that are maximally sensitive in the violet, blue-green and yellow-green wavelengths. Others such as the dolphin fish possess two cone pigments, while others such as the skipjack tuna have only one. Some fishes lack cones altogether and must rely on their extremely sensitive rods to distinguish any contrast between their prey and available light in their environment. Most colours in fish are due to pigments in the skin. But there are some which are caused by optical interference, notably in many butterflies and birds, but also seen in the varying hues of a dying dolphin fish.

Optical interference is the phenomenon that creates the rainbows on the surfaces of oily puddles. Optical interference exploits the wavelike nature of light. When beams of identical wavelength (i.e. the same colour) meet, their crests and troughs either add together to produce bigger crests and deeper troughs, or cancel each other out as the crests coincide with the troughs and fill them.

Because white light is made up of lots of different wavelengths, such effects are usually not noticeable. However, when an object (such as a scale on a butterfly's wing or a thin layer of oil on the surface of a puddle) contains reflective surfaces that are both parallel and very close together, the effects of interference become obvious. This is because individual light waves are reflected back and forth between surfaces and thus interfere with themselves.

The colour that emerges from such auto-interference depends on the distance between the reflective surfaces. In the case of light, whose wavelegth is an exact sub-multiple of this distance, crest falls on crest, and trough falls on trough, reinforcing the colour. Other wavelengths are destroyed, or at best emerge weakly.

61 Painful Pricks (They Jab and They Stab)



The sea can be a pleasant place to explore; it can also be a painful experience if one does not know how to go about it. There are many fishes that can be a nuisance, or even be dangerous to us. I am not talking of sharks (whose attack can even be fatal), but of small, innocent looking ones which can nonetheless be harmful.

In the course of evolution, fishes acquired fins. The tail fin enables a fish to swim forward. The fin on the back, acting as a sail, prevents the fish from rolling over. The paired pectoral (shoulder) fins, spread out sideways, are used as stabilisers. These fins are made of soft skin, and are stiffened by fin rays or spines. Primitive fishes, like sardines and herring, have only fin rays on their fins, but advanced ones like the perch group have, in addition, fin spines.

In some fishes, these spines, especially the ones on the fin on the back, are strong. When a fish is alarmed, its natural reaction is to erect them, and handling them carelessly is likely to lead to these spines piercing our hands.

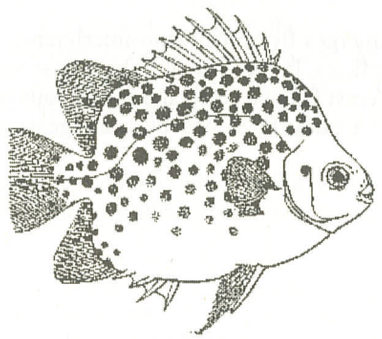


Fig.462 **Scat (*Scatophagus argus*)**

One such fish is the Scat (*Scatophagus argus*). The common name comes from a shortened version of the scientific name *Scatophagus*, which means offal eater. Though the fish is a vegetarian, it is not averse to feeding on excrement. *Argus* comes from the numerous spots on the body, and refers to the Greek god of that name who had a hundred eyes. It grows quite big (over 30 cm) and is good eating. It lives in estuaries, where rivers enter the sea and the water is not fully salty but brackish. As with all estuarine fishes, it can tolerate both fresh and sea water. The young, up to the size of a rupee coin, are prettily coloured in shades of emerald green and red, and are exported alive for keeping in freshwater aquaria. The fin on the back in large specimens has an array of sharp pointed spines, and the first spine on the pelvic fin is also long and stiff.

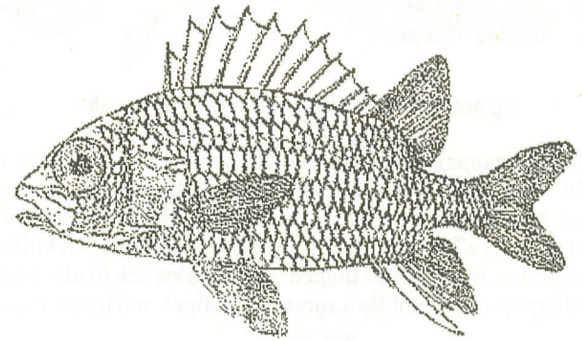


Fig.463 **Squirrel fish**

The squirrel fish (*Holocentrus rubrum*) is a coral reef dweller and grows to 15 cm. The body is a shiny crimson red with white stripes running along it. The stripes resemble those on a squirrel, hence the name. Its cousin, the soldier fish (*Myripristis murdjan*) also lives in coral reefs but lacks the white stripes, the body being a uniform crimson red. As sunlight falls on water, the red and orange fractions are absorbed first, and only the greens and blues penetrate deeper. In the 'twilight' zone of medium depths in the sea, any red object will appear black. Many crustaceans, especially prawns, living at these depths are coloured red. They also appear black at these depths and thus escape their enemies' notice. Squirrel and soldier fishes also have large eyes which help them to see in the gloomy, semi-dark depths. In addition to the spines on the back fin, there is an especially sturdy spine on the pelvic fin, as well as stiff ones on the pectoral (shoulder) fin.

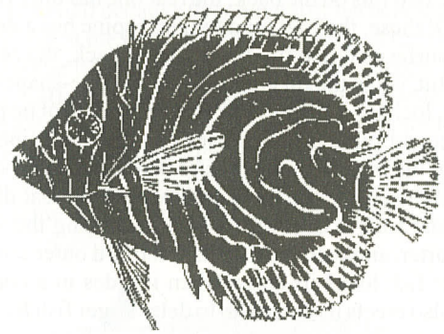


Fig.464 **Angelfish. Note horizontal dagger-like spine below gill-cover**

Marine angelfish (*Pomacanthodes*) also have stiff spines on the fin on the back, plus a dagger-like spine on the gill covers. Care should be taken while extricating such fish entangled in a hand net.

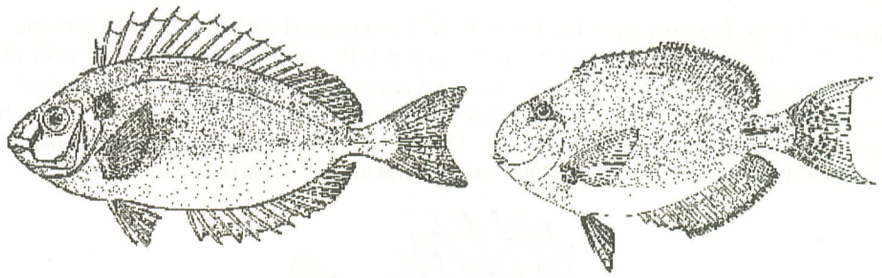


Fig.465 **Rabbit fish (left) and Surgeon fish (right)**

Rabbit fish (*Siganus*) also have strong, sharp pointed spines on all the fins except the tail fin. They are vegetarians, and so are their cousins, the tangs or surgeon fish (*Acanthurus*). The latter have a sharp edged spine, like the blade of a knife, on each side at the root of the tail (where the tail joins the body). As in a pen knife, this normally lies retracted in a groove, but it can be flicked out, like a switch blade, when the fish feels threatened. The sharp spine resembles a surgeon's scalpel, and hence its popular name.

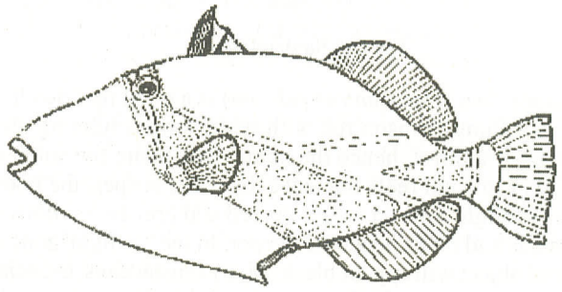
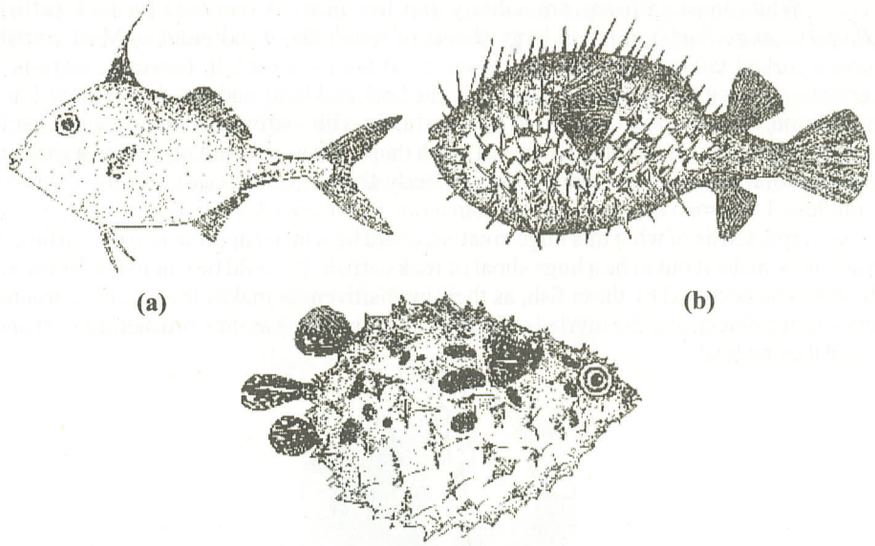


Fig.466 **Trigger fish**

Trigger fish (*Balistes*, etc.) also have a retractile spine, but this is situated on the fin on its back. There are two fins on the back; the rear one has only fin-rays, but the one in front has three spines. Of these, the first (and longest) spine has a deep V-shaped groove along most of its hind surface. When the fin is folded back, the second, much smaller, spine fits into the first. But, when the fin is erected, the wedge-shaped spine slides into the groove of the first spine, locking it firmly. The first spine cannot be pushed back by using force. Only when the second spine is pulled back can the first spine be folded back. The second spine is thus like the trigger of a gun, and hence the common name. The trigger fish has a large head and can easily crush sea urchins without fear of the latter's spines. It pushes the sea urchin and rolls it over on its back, exposing the vulnerable underside where the spines are shorter, and then crushes its test (hard outer covering) to feed on the soft insides. The trigger fish locks its spine when it hides in a coral crevice, so that it cannot be prised out. It also erects its dorsal fin to deter larger fish from swallowing it.

Closely related to triggerfishes is the tripod fish (*Triacanthus brevirostris*). It, too, has a long and sturdy dorsal fin spine as well as two equally strong pelvic fin spines. All three spines have a ball-and-socket arrangement, whereby these spines can be locked into position. In fact, when the two pelvic fin spines are locked, they form a tripod along with the tail fin.



(a) (b)

(c)

Fig.467 **(a) Tripod fish. (b) and (c) Two species of spiny puffer fish**

We also have the spiny puffer fishes (*Diodon*). Their spines normally lie flat against the body, but, when the fish is threatened, the spines are erected and stand out at right angles to the body, looking somewhat like the spiky steel balls attached to chains and used in mediaeval warfare.

In the fishes we have seen so far, the spines can inflict wounds. There are others more dangerous, where the spines have venom glands. When the spines jab an enemy, the venom can enter the enemy's tissues and cause a very painful sting or, at times, can even be fatal.

Catfishes are so called because they have soft barbels around the mouth just like a cat's whiskers. They live at the bottom where the water is turbid, so that good eyesight is of no help. To overcome this handicap, the sensitive barbels help them to touch and feel obstacles or prey. Catfishes live in fresh as well as sea water. All have a venomous spine on the first fin on the back as well as on the pectoral (shoulder) fin. A wound from these can be very painful. I remember a colleague who carelessly cut himself by a spine of a catfish which had died a day earlier. The venom was still potent and made him cry like a baby. In fact, some freshwater catfish (*Heteropneustes fossilis*) are known as stinging catfish because of the painful sting.

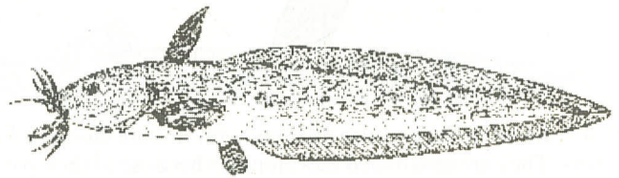


Fig.468 **Rock catfish.**

While most catfishes are solitary and live near the sea bottom, rock catfish (*Plotosus anguillaris*) move in large shoals of hundreds of individuals. Most catfish have a forked tail and two fins on the back. In the rock catfish, however, there is a continuous membranous fin running along the back and belly and fused with the tail fin. In addition, there is an isolated, short first dorsal fin with a strong venomous spine. I still remember my first encounter (in the sea) with them. I was sunning myself on a rock on the seashore when I saw a dark shadow nearly three metres across. As the day was cloudless, I assumed this to be a giant manta ray. However, its shape kept changing, and I was perplexed as to what this huge creature could be when it approached the surface. I could now make it out to be a huge shoal of rock catfish. It would be suicidal when skin-diving to be accosted by these fish, as their inquisitiveness makes them collect around any strange object, and the myriads of cuts from their spines as they brushed against one could then be fatal.

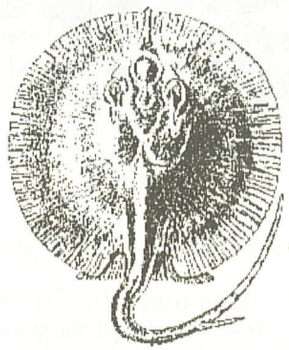


Fig.469 **Sting ray showing tail spine**

Sting rays have a saw-toothed spine (sometimes two or even three) where the whip-like tail joins the kite-shaped body. On the lower surface of this spine are two grooves containing venom glands. The sting ray whips its tail from side to side if accidentally trodden on while resting on the sea bottom. A jab from the spine can sometimes even be fatal, as large sting rays can have a spine 38 cm long.

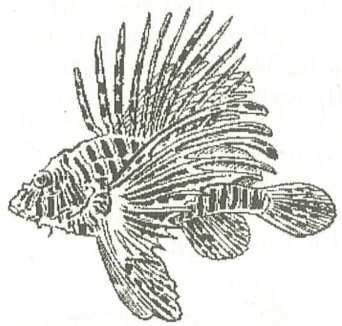


Fig.470 **Turkey fish**

Turkey fish are so called because their pectoral fins are elongated and frilled like a turkey's feathers. They are also called scorpion fish because of their painful sting. The two pectoral fins together form a sort of lace collar round the neck, like that worn by noblemen in the days of Queen Elizabeth I. This gives them their other name Lion Fish,

as this collar resembles a lion's mane. Males have two horn-like protuberances over the eyes. The venom is contained in the 13 dorsal, 3 anal and 2 pelvic spines. The long, slender spines are hidden in the delicate-appearing fins. In front of each spine is a glandular groove within which lie the venom glands. The latter are enveloped by thin integumentary sheaths. They are confident of their venom and will not swim away if approached by a skin-diver. They stay their ground, spread out their collar (pectoral fins) and erect the dorsal spines, ready to thrust if one is foolish enough to go any closer.

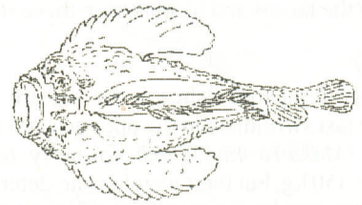


Fig.471 **Stone fish**

While a turkey fish's venom is extremely painful, there is another fish whose venom can be fatal to us. This is the stone fish *(Synanceia*). It is so well camouflaged that it looks like a piece of weed-covered stone. It is a poor swimmer and rarely ventures out in the coral reefs. Its looks, too, are hideous and indicate how horrible it is. (One species is even named *horrida*.) The sharp pointed hollow spines on the back can pierce rubber soles, and one should be extremely vigilant while wading on the shores of Laskhadweep or Andaman & Nicobar Islands, where they dwell.

So far, we have considered fishes that should be avoided because of their spines. There are others which are living javelins, jumping out of the sea when alarmed. Two fishes quite prone to such leaps are the garfish or needle fish (*Strongylurus*, formerly *Belone*) and half-beaks (*Hyporhamphus*, earlier *Hemirhamphus*). Both have the slender, elongated body, and fins of the back and belly placed far to the rear, characteristic of fast swimmers. While garfish have both the jaws elongated into a hard bony snout, half-beaks (as their name indicates) have only the lower jaw long, the upper jaw being short and tongue-like. They can jump high over the sea surface and can pierce one's neck or chest, inflicting a grievous injury. They do not purposely aim at us, but that is no consolation to someone smitten by them.

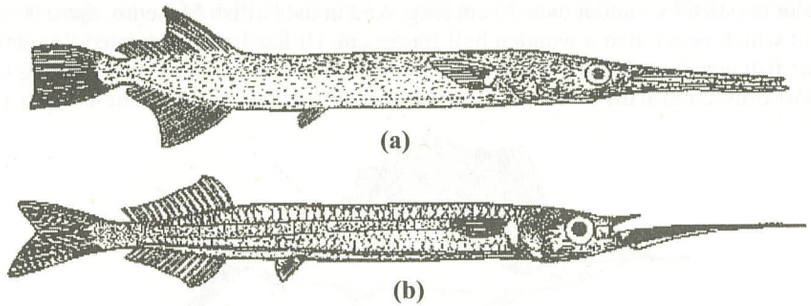


Fig.472 **Garfish (a) and Half-beak fish (b)**

Garfish grow to over a metre in length and there is one thing peculiar about them; their bones are green. The newly born young have short jaws. As they grow, the lower jaw lengthens, so that they look like half-beaks. Later, the upper jaw starts growing and ultimately both the jaws are almost equally long.

Their bones appear greenish or bluish-green because of deposition of bile pigments. Bile is formed in the liver from the breakdown of respiratory pigments in the blood, and helps in the digestion and absorption of fats from the intestine. Generally, the bile pigments are excreted in the faeces and urine, but in these fish they are stored in the bones.

Probably the most bad-tempered fishes in the sea are the group representing marlins or bill-fishes. All are fast swimmers in the open sea and are excellent game fish. The spear-fishes or marlins (*Makaira miitsukurii,* formerly *Tetrapturus brevirostris*) grow to 4¼ metres and weigh 450 kg, but their weight is no deterrent to their speed; they are among the fastest swimmers in the sea, capable of bursts of up to 65 km per hour. While swimming at speed, the fins of the back and belly fold into grooves. There are two flat, horizontal, wing-like keels on each side at the root of the forked tail fin. They feed on flying fish, sardines, mackerel and bonitos, and also on squids and cuttlefishes, and, in their turn, are preyed on by large sharks. The upper jaws extends forward in the form of a long snout, round in cross-section but pointed at the tip.

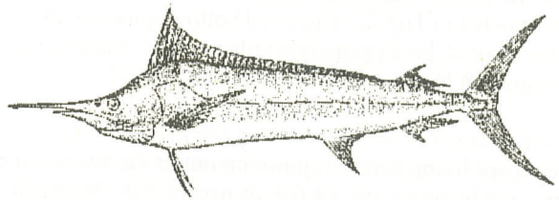


Fig.473 **Spear-fish**

Spear-fish seem to have a propensity for dashing into the hulls of boats and even ships. Once the snout has pierced the hull, the fish cannot reverse its swimming and so pull it out of the wood. In its struggle to free itself, the snout often breaks off and remains embedded in the hull. One of the earliest record, of an "attack" dates back to 1674. The College of Surgeons, London has a stout piece of timber, 34 cm thick, from the bow of a whaler impaled by a snout over 30 cm long. And in the British Museum, there is such a snout which penetrated a wooden hull for 55 cm. (It has been calculated that when a spear-fish weighing 270 kg and travelling at 16 km per hour, hits a boat moving in the opposite direction at the same speed, the force at the tip of its snout will be 4·5 tons.)

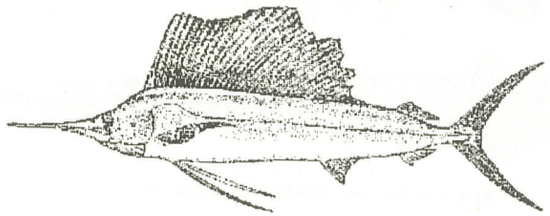


Fig.474 **Sail-fish**

Sail-fish (*Istiophorus gladius*) have a streamlined body and snout similar to that of spear-fish, but can be distinguished by the high, sail-like back fin. On calm days, they like to bask on the sea surface with the fin on the back fully spread and showing above the water.

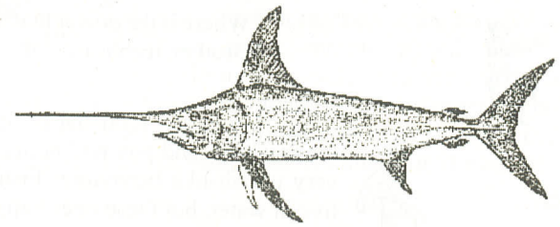


Fig.475 **Sword-fish**

Sword-fish or broadbills (*Xiphias gladius*) are cosmopolitan throughout warm seas. The snout is flat instead of round in cross-section; hence the name. They are the largest of the marlin group, growing to six metres in length.

During the day, adult swordfish are found predominantly in deep waters, where they feed at depths exceeding 300 metres. They rise to the surface waters to feed at night and return to deep waters before dawn. A small percentage will, however, lie at the surface even during daylight hours, in areas where the surface water temperature is between 20° and 15°C. It is believed that swordfish do this to aid digestion.

I was once involved in a legal suit. A wooden cargo-boat of 43 tons, bringing roof tiles from Mangalore to Dahanu, suddenly sprang a leak off Karwar. The crew had to jettison its cargo of 30,000 tiles to lighten the boat and prevent it from sinking. On inspection, they found a fish with its snout firmly embedded in the hull over a metre below water line. They had to cut it with a chopper before they could remove the 40- cm long piece and plug the hole.

When they claimed reparation for the loss from an insurance company, it was thought that it was a cock-and-bull story invented by the crew to account for the loss, so they sent me the piece to determine its origin. I had to sit in judgment and vouch for the authenticity of the story. The upper surface was smooth, but the lower surface was covered irregularly with white denticles resembling those of sharks. The extreme tip was broken off, probably by the force of impact.

62 Aquatic Olympics—Hop-skip-and-jump Champions of the Sea

"Where is the power that made your pride?"
"Brother, it ebbs from my flank and side."
Rudyard Kipling

Go to any mud-flat or mangrove swamp on the seashore, and you will notice some fishes with a very unfish-like behaviour. Fishes are supposed to live in water, but these ones happily bask in the sun, completely out of water, eyes vigilantly looking at you and heads slightly raised from the mud. The slightest move on your part and they are off and away, hop-step-and-jumping into the water. These fish are popularly known as mudskippers.

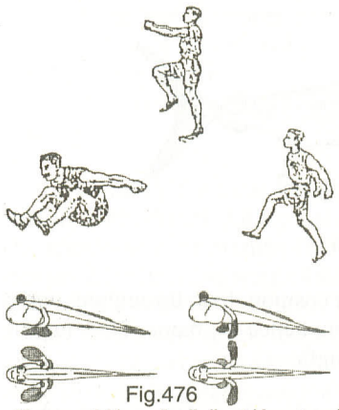


Fig.476
How a mudskipper "walks" outside water with the help of its pelvic fins. Viewed from side [upper row] and from above [lower row]

Mudskippers are part of a heterogeneous assemblage of sea-bottom fishes also comprising gobies, blennies, eleotrids and a few others. Apart from their bulging eyes being situated on top of the head, with well developed lower eyelids, mudskippers have their ventral fins completely fused to form a cup, and may have an elongated second dorsal fin (as in *Boleopthalmus*), or only united at their bases and with a short second dorsal fin (in *Petiophthalmus*). The well-muscled limb-like pectoral (shoulder) fins are used to crawl up outside water and hop about. The fish can also rear itself up on its tail and take off in 30 cm high jumps, changing its direction at each hop. The cup-like ventral fins act like a sucker, enabling the fish to hold tight on land.

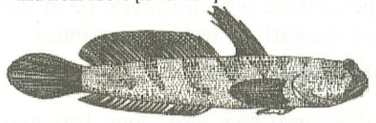


Fig.477 ***Boleopthalmus***

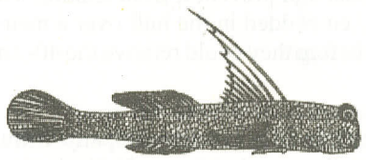


Fig.478 ***Periophthalmus***

In the nineteenth century, it was believed that mudskippers breathed by means of the tail. Old science textbooks often depict them basking with their body out of the water but with the tail dipping into the water. We now know that this is a fallacy. When a mudskipper ventures ashore, it carries a mouthful of air and water in its puffed-out jowls, and a dense network of blood vessels absorb the oxygen from it. Mudskippers are sold alive in fish markets, being kept in pots holding a little water, in which they seem to be quite comfortable.

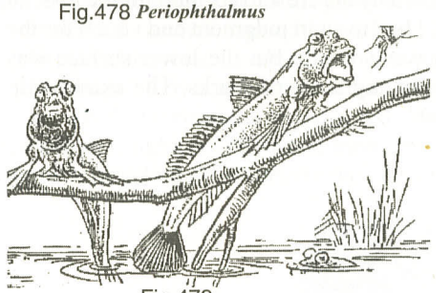


Fig.479
Earlier, it was [wrongly] believed that mudskippers breathe by dipping their tail in water

Gobies are more colourful cousins of mudskippers, also having united ventral fins, but while mudskippers have only one row of teeth in the lower jaw, gobies have two or more rows.

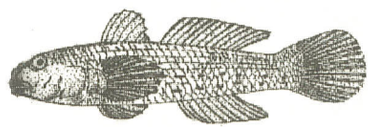


Fig.480 **The morse-code goby *Istigobinus ornatus***

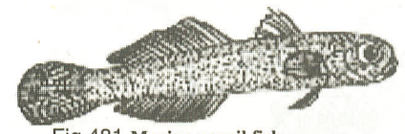


Fig.481 **Marine pencil fish**

Closely related to the gobies are the eleotrid fishes. They have their ventral fins close together but not united to form a sucker. An interesting form, which you will not find in fish markets is the tiny (25 mm) but very pretty marine pencil fish (*Parioglossus taeniatus*), which is so called because its long, slim, colourful body is akin to the freshwater pencil fishes of South America so avidly sought by aquarium hobbyists. This fish was not even known to occur in India until 1962, its native haunt being Aldabra, but it used to be very common at Cuffe Parade (in Mumbai), until most of this area was reclaimed.

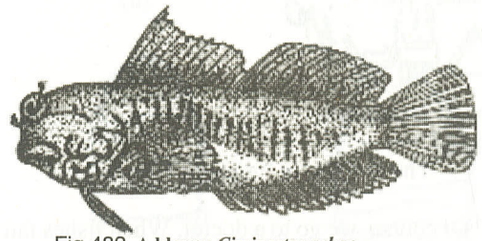


Fig.482 **A blenny *Cirripectus sebae***

Blennies are also related to most of the above mentioned fishes, but differ in having a shorter, more squat body, with a long dorsal fin (mudskippers, gobies and eleotrids have two) and thick, fleshy lips. Many (but not all) blennies also have a short tentacle with brush-like filaments above each eye.

Of interest to us is the sabre-toothed blenny, also known as false cleaner (*Aspidontus tractus*). It mimics the cleaner fish so well that fishes with parasites or festering wounds allow it to approach, thinking that it will rid them of the parasites. The wily blenny, instead, takes a bite and swims away. (See the chapter "Doctors At Sea".)

Fig.483 **Pearl-fish *Carapus***

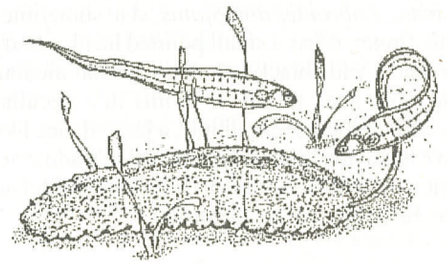
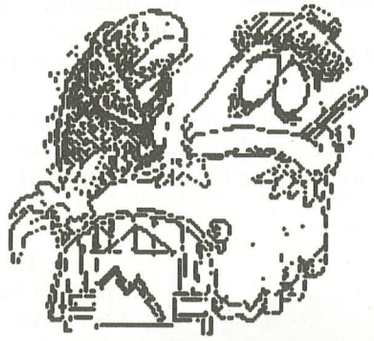


Fig.484 **A pearl-fish entering a sea cucumber tail first**

We finally come to the pearl-fish (*Carapus*). These are frail, transparent, elongated fishes without scales or ventral fins and with a tapering body looking like a paper knife. Some of them live in an oyster's mantle cavity. Sometimes the oyster, in protest, closes its shell valves and entombs the pearl-fish inside a coating of mother-of-pearl, hence the fish's name. But the majority of these fishes live inside the bodies of sea-cucumbers, entering the host, tail first, from the sea-cucumber's vent and living among its intestines. A strange preference indeed!

63 Doctors at Sea



Come, tell me how it is you live,
And what it is you do.
The Knight, in "*Alice in Wonderland*"

When we fall ill, what do we do? Of course, we go to a doctor. When fishes fall ill, what do they do? Do not be surprised; they, too, go to doctors who, moreover, have established clinics or dispensaries!

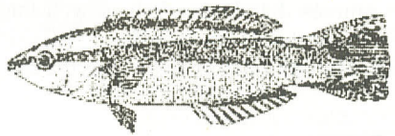


Fig.485 **Cleaner wrasse (*Labroides dimidiatus*)**

The "doctors" comprise some 45 species of fish, besides shrimps, but the commonest among them is the "cleaner" wrasse, *Labroides dimidiatus,* also sometimes known as "Blue Streak". As long as our little finger, it has a small pointed head, a body colour passing from blue to a delicate pink, and a wide black tail. A horizontal median black band runs along the body, widening from head to tail. It swims in a peculiar manner, oscillating the rear part of the body while progressing slowly, a jerky dance like a small boat pitching at a fast rate. If you have heard the last movement, titled Badinerie, of Bach's Suite No. 2 for flute and orchestra, you will be astonished whether Bach had set an amazingly faithful reproduction of this fish's movement to music.

Fig.486
Undulating swimming movement of blue streak when approaching its fish " patient ". (After Wickler)

Practically all fishes carry parasites, mostly small caligid or lermaeid copepods and isopods, on their bodies and on the gills. The cleaners do a good turn by picking them off and eating them. In addition, they will also pick at infected wounds to remove the diseased and dead tissue, and unwanted particles of food from the teeth, thus serving as dentists as well as doctors!

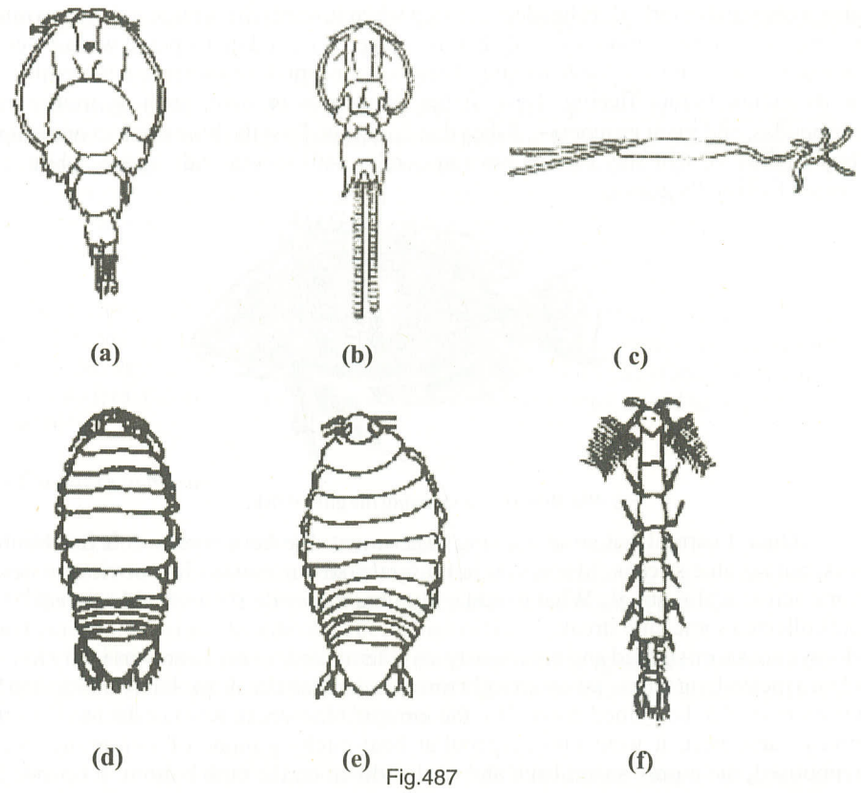


Fig.487
Copepod (top) and Isopods (bottom) parasites of fish

The blue streak lives in coral reef lagoons, mainly in shallow water of 60 cm, but are also found in water as deep as 60 metres. It establishes a "cleaning station"– a particular rock or coral head (shall we call it a clinic?) and does not move very far from this. Fishes requiring to be cleaned soon come to know of this location and visit it from long distances away. To indicate to the cleaner fish that they wish to be "serviced", they assume awkward postures: on their sides, head up, head down, or upside down. Some change their body colour dramatically. They will hold their fins extended and held rigid, and their gill-covers open. Sometimes large crowds will gather at a cleaning station. If they are docile, they will simply jostle around the blue streak, but aggressive fishes like surgeon fish or jacks may even scrap with each other, like bullies breaking a queue at a bus stop. As many as 300 fishes are known to have been serviced in six hours.

On receiving the proper signals from its "patient", the blue streak swims in the peculiar manner described above. It will rush forward, turn sideways, extend its fins and then retreat, repeating the process. It also raises the front part of its back fin to form a conspicuous black triangle.

The fish to be cleaned will allow it to move all over its body, and even inside its mouth, to allow the cleaner to reach its gills and clean its teeth. When it can no longer hold its breath, it will give a signal to the cleaner fish to come out. Thus a moray eel will

give a convulsive jerk of its head to one side when it wants the wrasse to leave, while a grouper will close its mouth sharply but not completely, and then open it wide. Even in case of sudden danger to the fish being cleaned, it will spit the cleaner fish forcefully out of its mouth before fleeing. Even fishes dangerous to man, such as moray eels barracudas, and giant groupers– fishes that could swallow the blue steak in one gulp if they wished to, will stay motionless and docile, with mouth wide agape, while the cleaner fish boldly goes in.

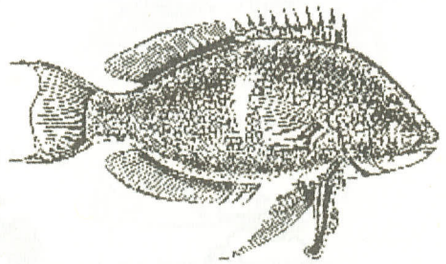


Fig.488 **Blue streak cleaning the gills of fish.**

Once I carried out an interesting experiment. We have moray eels in Mumbai seas, but no blue streaks. Morays do not migrate, so our morays had obviously never come across a blue streak. What would a Mumbai moray do if it met a blue streak? We had collected some blue streaks from Sri Lanka, so I introduced one into the moray tank. Morays are short-sighted and notoriously short tempered, so my heart was in my mouth when a metre-long moray swam straight towards the blue streak, probably taking it to be a tasty morsel to be gulped down. But the intrepid blue streak was not daunted. As the moray came near, it went into its peculiar boat-pitching mode of swimming. As if hypnotised, the moray swam back and settled down on the tank bottom. It opened its mouth wide and allowed the blue streak to groom it. It is a clear case of instinct overcoming the unknown.

A wily fish, the sabre-toothed blenny (*Aspidontus taeniatus*) takes a mean advantage of the fish patients' knowledge that cleaner wrasses help them by removing parasites and festering skin. This fish has an uncanny resemblance to the cleaner fish, so fish patients, thinking it to be a cleaner fish, allow it to come close. The blenny takes a quick nip, biting off a chunk of flesh and escaping before the patient can recover its wits. Such a type of mimicry is called aggressive or Peckhammian mimicry, where a predatory (and hence harmful) animal resembles a non-predatory (and harmless) animal. In common parlance we can call it a wolf in sheep's clothing.

Many a time, while hovering motionless over a coral bed, I have been the focus of the cleaner fish's, not unwelcome, attention. While engrossed in watching something interesting on the sea bed, I would feel a gentle tugging of the hairs on my legs, or, sometimes, of the many healing scratches with clotted blood which every aqualung diver manages to acquire however careful he may be. After some time, the blue streak would realise the futility of removing (non-existent) parasites from my skin and would swim away to seek better pastures.

But just once did I really wish that a cleaner fish had been present to "service" me. That was on the approach march in the foothills of the Himalayas, on a long trek to

reach our goal, a mountain peak in Sikkim. We were still in grass country, and, in the evening I had gone to a meadow of tall grasses for nature's call. While squatting, I saw a yak grazing nearby, bud did not pay much attention to it. That night, I felt a peculiar sensation an inch to the right of my navel; it was a small pea-sized swelling. I realised that I had unwittingly picked up a tick in the meadow, and it was happily gorging itself on my blood. Now the best way to get a tick to fall off without leaving its mouthparts in our flesh is to rub salt or tobacco juice on it. At the first light of dawn, I told my tent partner, a captain in the Gurkha regiment, about my woes. He enjoyed a smoke first thing in the morning, and listened as I indicated the site of my troubles, near my navel.

Now I have a dark mole an inch to the left of my navel (remember that the tick was an inch to the *right*). In the semi-darkness, my partner could vaguely see a dark spot against the fair skin of my belly, and, thinking this to be the tick, jabbed his lighted cigarette onto it to dislodge the tick. That was one occasion when I would have preferred a cleaner fish.

Other Cleaners in Nature

Removal of skin parasites on one animal by another seems to be a common phenomenon in nature. Such instances on land have long been known, e.g. the crocodile and the Egyptian plover, domestic cattle and egret, and rhinoceros and tick bird.

On the seashore, crabs remove ticks from sunbathing iguanas (lizards) in the Galapagos Islands. Sea gulls "clean" ocean sunfish (*Mola mola*), while wrasses pick at the shell of sea turtles; other wrasses clean parrotfish.

It was a long accepted notion that sucker-fish (remoras), found sticking to sharks, feed on the scraps of food left over by a feeding shark. But these too have been observed entering the mouths or gill chambers of large fish like swordfish, sailfish and ocean sunfish. Parasitic copepods found in the stomachs of remoras indicate that they are, at least partially, parasite cleaners. And the pilot fish, which superficially resembles a remora, but does not have a sucking disc, cleans the jaws of manta rays.

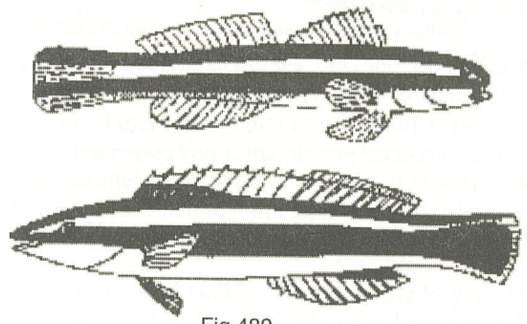


Fig.489
The role of a cleaner, which is undertaken by the blue streak (lower) in the Indian and Pacific Oceans, is fulfilled by the neon goby (*Elscatinus*) in the Atlantic. Note similarity in colour.

Pennant fish (*Heniochus*) clean groupers and goatfish. In the Nicobar Islands, cardinal fish (*Siphamia versicolor*) shelter between the long spines of the sea urchin *Diadema*.

The sea urchin tilts its spines together in small pyramidal groups which exposes the interradial fields, and the cardinal fish then picks at these surfaces to clean them.

In all the above instances, the cleaning agent does not depend solely on its cleaning activity for earning its food; it is a part-time job. But there are others who are compulsive cleaners. In addition to *Labroides dimidiatus*, three other species of *Labroides*, viz. *bicolor, phthirophagus* and *rubrolabiatus* will even clean *Labroides bicolor.*

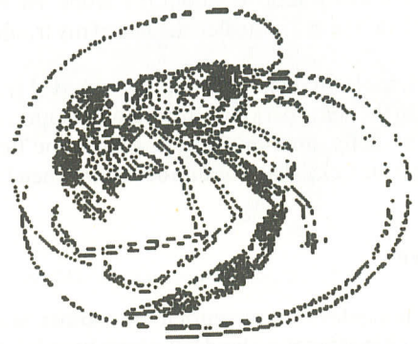
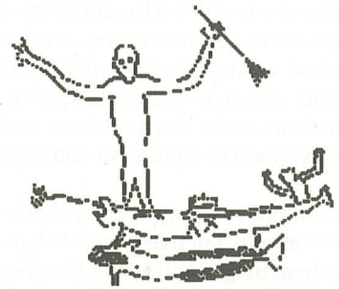


Fig.490 **Cleaner shrimp (*Stenopus hispidus*)**

Shrimps belonging to three genera– *Stenopus, Hippolysmata* and *Periclimenes* do full-time cleaning jobs as efficiently as cleaner fishes.

64 Hitch-hikers of the Sea



The sucking-fish beneath, with secret chains,
Clung to the keel, the swiftest ship detains,
The seamen run confused, no labour spared,
Let fly the sheets, and hoist the top-mast yard,
The master bids them give her all the sails
To court the wind and catch the coming gales,.
But though the canvas bellies with the blast,
And boisterous winds bear down the cracking mast,
The bark stands firmly rooted on the sea,
And will, unmoved, nor winds nor waves obey;
Still, as when calms have flatted all the plain,
And infant waves scarce wrinkle on the main.

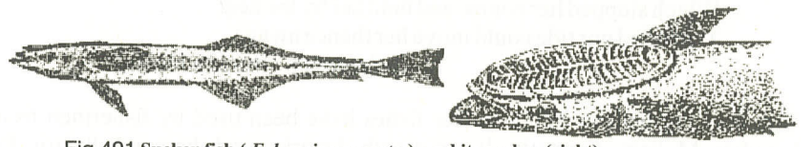


Fig.491 **Sucker fish (*Echeneis naucrates*), and its sucker (right)**

Sharks may be the monarchs of the sea, but there is one fish that makes a sucker of them– the remora or sucker fish. Go out in a boat in the harbour, and chances are that you will see one or more of them swimming near the hull. Observe one closely and the thing that immediately impresses you is the oblong suction disc on top of the flat head. This is made up of two parallel series of transverse plates, set in a long oval frame. These plates move like the slats of a venetian blind and, when raised, create a partial vacuum. Numerous tiny spines slope backward from the ridges and provide additional friction.

There are several types of sucker fishes, and the largest grow to over a metre long. They attach themselves to a variety of fish, including sharks, barracuda and sting rays, turtles, whales, floating driftwood and even boats. The remora has a black band with white borders running along its body. When it clings upside down on the back of a fish, as it often does, the usual colouration (dark on the back, white on the belly) is reversed. Its ability to thus change its colouration, coupled with the fact that it often clings upside down onto the back of a shark, gives it its sixteenth century Spanish name "Reverso" (upside down fish).

The suckers are merely energy saving mechanisms, allowing the remora to hitch a ride, somewhat like a lazy cyclist clinging to a slow moving lorry. Once attached, it can relax its muscles. The faster the shark swims, the greater the suction force. And the power of suction is tremendous. A 60-cm long sucker fish was allowed to attach to the inside of a bucket filled with water, weighing 9 kg in all. When the remora was picked up by its tail, the bucket came up along with it. (Do not carry out this experiment; it is cruel to the fish and may damage the sucking disc or even break its backbone.) However hard you may pull it backwards, you will not be able to dislodge it. Even a dead sucker fish is hard to remove from a smooth object, as long as the pull is from the rear. To remove it, push the head forward (this lowers the flanges of the sucking disc), or pinch the disc from both sides, which permits water or air to enter and equalise the pressure.

Sucker fish are not immune to being eaten by sharks. They take care not to tempt the shark by hovering near its mouth, but live sucker fish have been found inside sharks' mouths; they probably got there by going through the gill slits. At public aquariums, a new sucker fish is introduced only after the sharks have had a meal.

The ancient Greeks and Romans were greatly impressed by the sucking power of the remora, and believed that it could slow down or even stop a moving ship. The Latin name 'Remora' means 'holding back', and the scientific name for sucker fish *Echeneis* comes from two Greek words meaning 'to hold back'.

Emperor Caligula's death was attributed to a sucker fish fastening onto his ship and holding it back against the exertions of 400 oarsmen allowing enemy ships to overtake it. When the hull was examined, there was found attached to it a remora– indisputable proof (to the sailors) that this small fish had held the galley back.

When suddenly there clave unto her keel
A little fish that men call Remora
Which stopped her course and held her by the heel
That wind nor tide could move her thence away.
In Spenser's "*World's Vanity*"

You may not believe it, but sucker fishes have been used by fishermen from India, Zanzibar, Malaya, Australia, Japan, South America and the south Pacific for catching turtles. Accounts of these 'hunting fishes', when they were first published in Europe in 1504, were not merely disbelieved, but widely ridiculed.

The method is simple. When the fishermen sight a turtle, the sucking disc of a captive remora is vigorously scrubbed with dry sand to remove slime. A ring of rattan is fastened around its tail, just tight enough to prevent it from slipping off, and to this is tied a length of thin but strong cord. Weary of having been tethered in the boat, the sucker fish, as soon as it is liberated, dashes off towards the turtle, and attaches itself to its shell. The fishermen then reel in their catch– fish, line and turtle.

While on the subject of animals used for fishing, otters have been trained in the Sunderbans of Bengal to herd fish into a net. And cormorants are trained in China and Japan to catch fish. A ring made of string is tied around the lower part of the bird's neck.

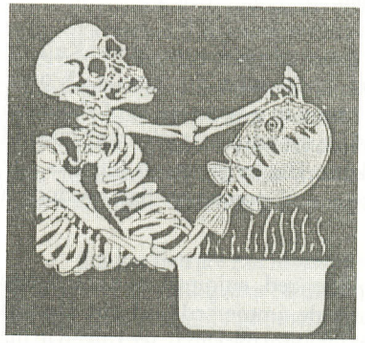
The cormorant can now swallow small fish, but not large ones. Up to a dozen cormorants, tied individually to leashes, are taken on a boat to the fishing ground, and then released into the water. When a cormorant returns with a fish and gives up the catch to its owner, it is promptly rewarded with a piece of fish.

Another unique method of fishing is used by fishermen of Kanjrode and Kallada village near the Ashtamudi 'lake' of the Quilon backwaters in Kerala. I once accompanied a group of them, rowing in a dugout canoe to a secluded spot sheltered from the wind. It is well known that many fishes produce sound; that is why the Sciaenid family of fishes are known as drummers and croakers. The target perch squeaks, the silver belly makes a grating noise, and triggerfishes and porcupine-fish produce a gnashing noise with their teeth.

The man at the bow, who was the most experienced, enjoined us to complete silence, got into the water and holding on to the gunwale, immersed his head. He was 'listening in' for the sound produced by the fish. After locating the shoal, we rowed to the spot and spread our gill net in a circle. After encircling the shoal, the fishermen tapped the sides of the canoe, gradually tightening the circle. And lo! There was a shoal of fish inside, jumping nervously about. I was told that experts could tell from the sound whether a shoal was at rest, feeding or moving; and even roughly determine its size. The Malays on the east coast carry on their payang fishing in a similar manner. Talk of Asdic or Sonar!

It is a pity that these quaint but romantic methods of fishing are slowly being given up, and replaced by high but dull technology.

65 Poison in the Pot



These ye shall eat of all that are in the waters;
All that have fins and scales shall ye eat;
And whatsoever hath no fins and scales you may not eat;
It is unclean unto you.

Deuteronomy 14:9-10

Many of the fishes caught in the sea are not seen in fish markets. One kind that you will never see in Indian markets are the puffer fishes or globe fishes. It is not that they are rare; when they come in fishermen's nets, they are thrown back into the sea.

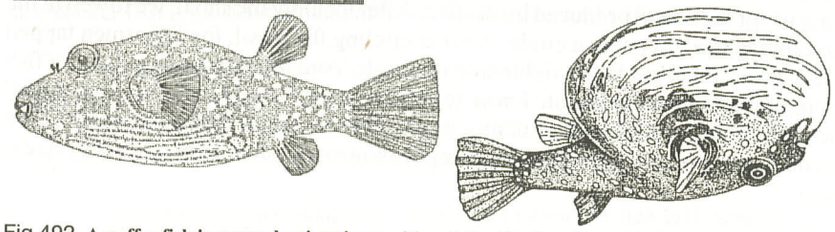


Fig.492 **A puffer fish in normal swimming position & floating inertly upside down when inflated**

The puffer fish has a globular body without scales. When harassed or threatened, it literally puffs up by gulping water which is retained in an offshoot of the stomach. The blown-up body will remain distended for some time, during which the fish floats upside down on the water surface. When thrown ashore, it swallows air instead of water, accompanied by a noisy grinding of the teeth.

The reason why you will not see puffer fish in our markets is because of their deadly poison. The flesh can be eaten, but their skin, liver, roe and gut contain a very potent poison. Death may occur in a few hours, and there are no antidotes. Soon after eating, there is a tingling sensation in the lips and tongue, developing into numbing of the extremities and then of the whole body. This is accompanied by lowered body temperature, profuse sweating and saliva flow, low blood pressure, headache, extreme weakness, nausea and anxiety. Vomiting, severe stomach ache and diarrhoea follow. After some time, the breathing becomes shallow and rapid, the lips and fingertips turn blue, muscular twitching, trembling, slurring of speech and respiratory paralysis set in, the last resulting in death in six to 24 hours.

The poison is called tetrodotoxin, from the scientific name (*Tetrodon* or *Tetraodon*, meaning four teeth) of puffer fish. By a rare coincidence, the same poison is also found in the eggs and embryos of the California newt (*Taricha torosa*) and in the octopus *Hapalochlaena maculosa* (but here as a venon). Tetrodotoxin is a nerve poison 1,000 times more potent than potassium cyanide (KCN) and 160,000 times more active than cocaine.

Tetrodotoxin (TTX) is a powerful muscle relaxant, and is actually a combination of different compounds produced by bacteria of the genera *Vibrio, Alteromonas, Bacillus* and *Pseudomonas*. TTX is also present in the crab *Atergatis floridus*, the horseshoe crab *Carcinoscopius rotundicauda* and the sea star *Astropecten polycanthus*.

Surprisingly, the Japanese eat puffer fish, which they call "*fugu*", and consider as an epicure's delicacy. In Japan there are catering colleges where chefs are trained to dress *fugu* carefully so that not even a trace of the poisonous parts of the fish's body gets into the dish. Only after passing a tough examination and earning a diploma can a chef prepare *fugu* in specially licensed restaurants. The only way to inactivate the poison is to cook puffer fish in a strong solution of baking soda, but then the flavour of the fish is destroyed and the fish is hardly worth eating.

Why do the Japanese esteem puffer fish? Perhaps because of the state of exhilaration (akin to having alcoholic drinks) giving rise to a sensation of warmth, flushing of the skin and a feeling of euphoria caused by the mild effect of the small amount of poison still remaining after preparation. A Japanese sage, Hosetsu Namba, aptly said over a hundred years ago: "Although there are many occupations in the world, some people engage in stealing instead of entering one of them. Although there are many women in the world, there are some men who become adulterers instead of marrying the women. Although there are many kinds of foods in the world, some people like to eat poisonous *fugu* instead. These three groups of people make up an extremely stupid trio."

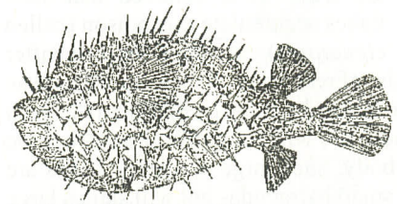


Fig.493 **A spiny puffer fish**

Closely related to puffer fishes is the spiny puffer fish or burr-fish (*Diodon hystrix*). Its body is beset with many spines. These normally lie flat against the body, but when the fish puffs up its body, the spines are erected, posing a formidable deterrent to its enemy. In the far east, they are blown up and dried, and a candle is placed inside so that they serve as a lantern.

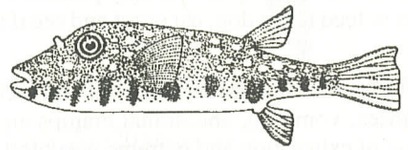


Fig.494 **A sharp-nosed puffer fish *toby***

Distant cousins of the puffer fish are the sharp-nosed puffer fish or toby (*Canthigaster*) and box fish. Tobies have scales like the velcro which is used instead of buttons or zippers to temporarily stick a cloth to another. These scales, plus sticky slime which acts like glue, help the fish to stick firmly to a reef at night. With their poisonous body, they can sleep securely.

An excellent example of Batesian mimicry is provided by the black-saddled toby or sharp-nosed puffer fish (*Canthigaster cinctus*, also known as *C. valentini*). In this type of mimicry, a harmless animal or fish (called the mimic) resembles a harmful or distasteful animal (called the model). As are all puffer fishes, this toby too is poisonous, and is, therefore, avoided by predators. A completely different fish, *Paraluterus prionurus*, which is actually a file fish and therefore non-poisonous, has a remarkably similar colour pattern on its body as that of the black-saddled sharp-nosed puffer fish. Predators are confused into thinking this fish to be a poisonous toby and, therefore, avoid it.

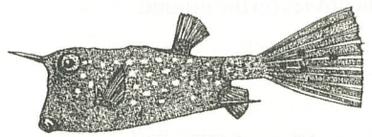


Fig.495 **A cow fish**

In the box fish, the body is encased in a hard bony armour, with holes only for the mouth, fins and tail. One kind of box fish has two spines on its head, and is aptly named cow fish (*Lactoria*

cornuta).

In the tropics, and especially in coral reefs, there are many fishes which are edible. However, in some places or at some times, these become poisonous to eat. This kind of poisoning is called ciguatera, derived from a Spanish word. Fishes may be safe to eat on one side of an island, but are poisonous just half a kilometre away on the other side. Or fishes on an island which have been eaten over many years may suddenly become poisonous to eat.

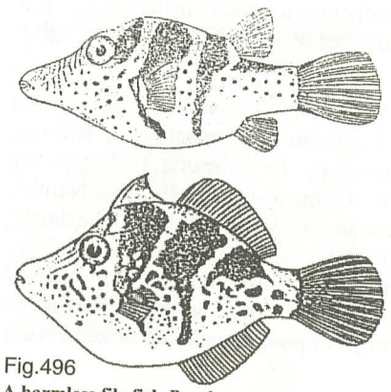


Fig.496
A harmless file fish *Paraluterus prionurus* [above] mimicking the poisonous toby *Canthigaster cinctus* (below)

Ciguatera poisoning should be distinguished from ptomaine poisoning, which is caused by eating stale (spoiled) fish that have been tainted with bacteria. Almost every fish-eater has, at some time or the other, suffered from this. Ciguatera-causing fishes will affect humans (and other mammals) even when they are fresh. It is believed that such fishes accumulate this poison (called *ciguatoxin*) in their bodies after grazing on certain kinds of algae or seaweeds. (Freshwater fishes do not cause ciguatera.) The fish does not suffer any ill effects. It may be eaten by another fish, such as snapper, grouper, barracuda or moray eel. These too will not suffer illness, but the poison from their prey will accumulate in their body. Such large predatory fishes are especially dangerous to eat. Islanders readily eat small barracudas but will shun a large one.

There is no test to determine if a fish will cause ciguatera. The only precaution one can take (apart from not eating fish at all) is to feed it to a dog, cat or rat and see if it dies.

A person suffering from ciguatera will experience a sudden onset of stomach ache, dryness of mouth and metallic taste, nausea, vomiting, abdominal cramps and fluid motions. There is also body ache, a feeling of exhaustion and extreme weakness; the victim is unable to walk. The teeth feel loose and painful in their sockets. In severe cases, there may be a loss of hair and nails. Some twelve out of a hundred affected people may die.

But the classic symptom of ciguatera poisoning is a reversal of the feeling of heat and cold. Thus a victim may complain that his ice-cream is burning his tongue or that a cold shower bath is scalding his skin!

An ailment somewhat similar to ciguatera is also found in sea-gulls after they have consumed fish poisoned by certain planktonic forms. The basic toxin, called domoic acid is produced by these forms and then transmitted along the food chain to fish such as anchovies. The brain of the sea-birds is damaged, so that they become disoriented and crash into houses, throwing up the anchovies on the ground.

66 Meet the Mighty Mola

My basking sunfish know it,
And wheeling albatross,
Where the lone wave fills with fire
Beneath the Southern Cross.

Rudyard Kipling

One of the rarest fish that I have come across, is also the weirdest looking and the largest marine bony fish. I am referring to the ocean sunfish, which scientists call *Mola mola*. Both the names are appropriate; *Mola* in Latin means millstone, which describes the circular but flat body, while the English name refers to its habit of lying on one side on the sea surface, basking in the sun.

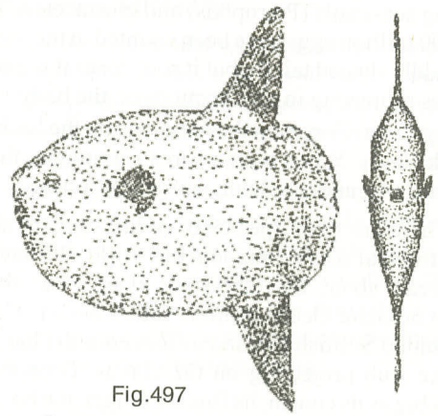


Fig.497
Common or Giant Ocean Sunfish (*Mola mola*)

The ocean sunfish is huge– 3 metres long and weighing close to a ton. At a first glance, the fish looks as if a shark has bitten off its body leaving only the head and vertical fins. This is because the vertical (dorsal and anal) fins are set far back, and the tail is lost in infancy, being replaced by a stiff, hinged, flap-like structure called clavus. Because of this shape, it is also sometimes called "head-fish". Due to the shortened body, the internal organs are shifted forward; even the kidneys are situated just behind and above the skull. There is no air-bladder. The number of vertebrae (backbone) is also reduced to 16 or 17. (Other fish have 35 to 70 vertebrae.)

The body colour varies from deep blue to olive brown or grey. The young have round dark spots on the rear of the body. Below the tough, leathery skin is a 5- cm thick layer of gristle, but the bones have degenerated and are quite soft. Above the eyes are bony ridges looking like eyebrows. The mouth is tiny and constantly open. The teeth in each jaw are fused to form a hard beak.

Ocean sunfish are related to triggerfish, porcupine– and puffer– fish, as can be seen from the beak in the mouth, reduced number of backbone units and the absence of scales and pelvic fins (the paired fins on the belly). Like in their cousins– the puffer fish, the skin has a thick coating of slime which contains tetrodotoxin– the powerful poison that makes puffer fish deadly to eat. Yet the Japanese relish the milky white, oily flesh, often eaten raw.

The ocean sunfish is mostly seen alone or in pairs, but sometimes in small groups of 10 to 12, lying motionless on the sea surface. From time to time, it will roll over so as to expose its other side to the sun. Considered lazy and stupid, on the approach of a boat it will sink a few metres to resurface behind the boat. Even when repeatedly jabbed by a harpoon, instead of diving down which it can easily do it will stay put to be killed. When captured or hurt, it utters sighs or groans and grunts like a pig.

It swims by using the large dorsal and anal fins, which bend to the same side at a time. The clavus (false tail) is used like a rudder for turning left or right, while the paired pectoral fins (the ones behind the gill-cover) flap like an elephant's ears. Powerful jets of water are sometimes squirted out from the gill-openings to speed its movement, and the mouth can also shoot out water (but not for swimming).

Being such sluggish swimmers, it is no wonder that they serve as a dwelling for various creatures. Sucker fish take shelter in the gill-chambers. Parasitic copepods, as long as 5 cm, latch onto the gill-filaments, while others half this size lodge in large numbers near the eyes and onto the chin and throat. Circular, transparent, disc-shaped flatworms (Platyhelminthes) over 2 cm in diameter with two opaque suckers stick to the skin. The liver is so riddled with roundworms that it resembles a sponge or a piece of wood attacked by shipworms. The gut also shows lumps and nodules where parasites have embedded in it.

Its favourite food is jellyfish, but it also feeds on the leaf-like young (called leptocephalus) of eels, other fish, swimming sea-snails (Pteropods) and crustaceans. It seems to be a prolific breeder; as many as 300 million eggs have been counted in the roe. The tiny (2·5 mm) young have a normal, paddle shaped tail fin but it soon loses this and instead acquires a veritable armour of spines projecting in all directions on the body. A little later, five of these spines grow into long "horns"–one on the nose, one on the back, one on the chest, and one on each side of the body. When it grows to a centimetre, the spines shorten, the body becomes deeper than long, and the clavus (false tail) appears.

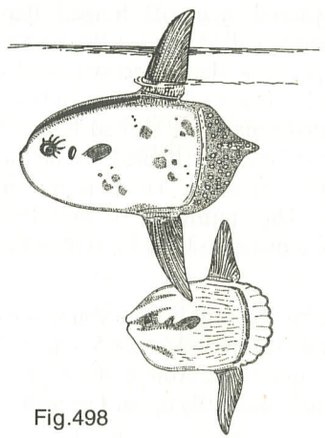


Fig.498
The Pointed - tail sunfish
(*Masturus lanceolatus*) (above)

There are three species of ocean sunfish, all found in tropical seas throughout the world. We have already read about the largest of these, viz. the Common or Giant Ocean Sunfish (*Mola mola*). The Pointed-tailed Sunfish (*Masturus lanceolatus*) has a finger-like stub projecting on the clavus. Growing almost as big as its cousin, its fins are longer, the body less high, and the rear of the body is adorned with polka dots.

The third, called Oblong, Slender or Truncated Sunfish (*Ranzania truncata* or *Ranzania laevis*) is much smaller, growing only to 78 cm and is very slender. The vertical fins are shorter and the false tail very narrow. The body is dark steel-grey above, merging to silver on the sides and belly. The silvery sheen is easily rubbed off by handling, exposing a fleshy pink with a honeycomb design of slightly darker red. The sides of the head below the eyes have parallel silvery stripes with black borders, extending backward as gradually diminishing stripes on the belly. The pinkish brown tail has about 18 finger-shaped dark spots at right angles to its border; these indicate the positions of the fin-rays below the skin.

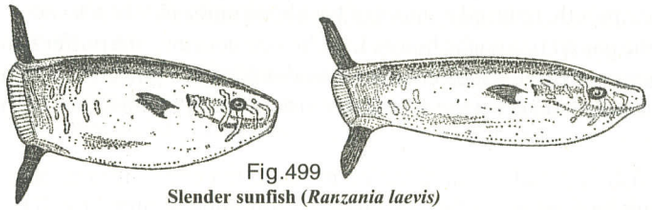


Fig.499
Slender sunfish (*Ranzania laevis)*

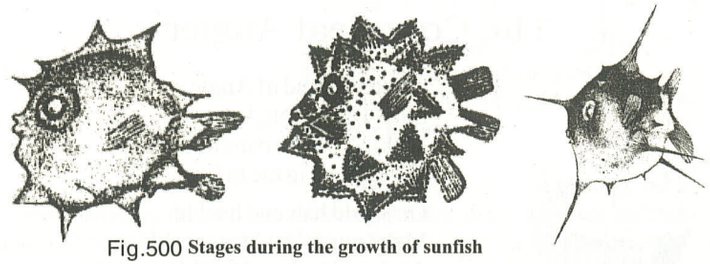


Fig.500 **Stages during the growth of sunfish**

The young of the ocean sunfish are so different from the adults that they were earlier thought to be different species. Soon after hatching, the minuscule (3 mm) larva develops a suit of armour which resembles the head of a mediaeval mace. In one species, five spines later turn into long, horny spikes. These larvae then change into a 2.5 mm body that is deeper than long, with shortened spines and a new, single tail fin.

My encounter with the sunfish came as a lucky strike. A fisherman had landed one in his catch and was perplexed, as neither he nor any other fishermen had seen anything like it earlier. By now, our Aquarium had established a rapport with local fishermen, so that they would bring in rare or unusual specimens to us. (The fact that they were paid handsomely helped a lot!) And I had also by then established a sort of reputation that any unusual marine creature could be identified by me. I also took pains to explain to the fishermen who brought these creatures about their life habits and peculiarities. So, although this fish had no market value (no one ventures to eat an unknown fish), the fisherman carefully put it in ice and brought it the next day. Identifying it took only a few minutes, as I had seen illustrations of the fish earlier. Referencing earlier records was another matter, but it turned out that this was the second record of this species from India.

The Polynesians revered the Oblong Sunfish and called it "king of the mackerels". In Hawaii, people believe that all Scombroid fishes (tuna, marlin, etc.) are subject to the rule of the Oblong Sunfish (which they name as "makura"), and that the former will disappear if the *makura* is killed.

67 The Compleat Angler*

Angler in land of Angle,
Shall I do to dangle,
Making water spangle,
When you dip me in?

Or would hair and heckle
Make much brighter speckle,
As you scorch and freckle,
Watching gill and fin.

Through the seasons, I have seen many persons taking their ease on the seafront, holding an angling rod with rock-steady hands, motionless as if in yoga-like meditation, seemingly attuned to Nature. I have marvelled at their immense patience, gazing out for hours on end until the hum of their line sends them into a flurry of activity, reeling in their fish catch. Normally taciturn, they will open up if you evince interest in their hobby, explaining the fine points of various types of rod, and may even let you in on their favourite but secret bait.

The essential requirements for an angler are: a good, light, flexible rod, a bait tempting enough in appearance and movement to lure a fish, and plenty of patience. These requirements are fully met with– don't be surprised– in a fish.

Aptly called the angler fish (*Antennarius*), you will be lucky if you come across one in a rock pool at low tide. It is rather uncommon, and it is so nicely camouflaged that you might be looking at one without seeing it. With a dumpy, misshapen body the size of a lemon, and beady, expressionless eyes, it is not exactly pretty, the grotesque white body with numerous brown streaks looking like a lump of fat.

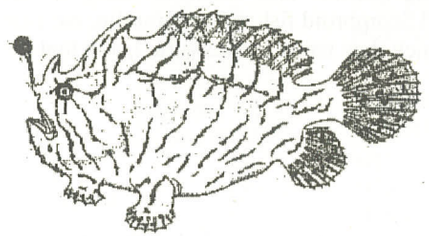


Fig.501 **An angler fish**

Above its widely grinning mouth is a jointed "angling rod", at the tip of which is the "bait" in the shape of a feather-dusterlike tassel. The fishing rod is actually the first spine of the fin on the back which, over millions of years, has migrated forward until it lies just above the mouth, and has become modified in shape and function.

The fish conceals itself in a gently swaying bunch of seaweed. Here it remains motionless, camouflaged in the same way as is a tiger in a thicket of reeds or bamboo. All that moves is the rod and the bait. But the sight of a prey fish sends it into a flurry of activity. The rod is rapidly flicked to and fro so as to make the tassel gyrate oddly. And woe to the fish which gives in to its curiosity. As it swims near to investigate, the jaws and throat of the angler fish are galvanised into surprisingly rapid activity, and its victim is instantaneously sucked into the gaping cavern of a monstrous mouth, the jaws shutting with a snap.

When thou will swim in that live bath,
Each fish, which every channel hath,
Most amorously to thee will swim,
Gladder to catch thee than thou him.

For thee, thou needs no such deceit,
For thou thyself art thine own bait;
That fish that is not Catch'd thereby
Is wiser far, alas, than I.

Doctor Donne.

When the fish is not hunting, the rod folds down and the tassel snuggles down into a little pit between the two stout fin-spines immediately behind the fishing rod. And while other fishes swim, the angler fish "walks". Its four paired fins are modified into hand-like feet, complete with elbow joints. Though the angler fish is the embodiment of ugliness, one cannot help laughing when, seeing a prospective prey, it rolls its body from side to side like a tottering drunk. All this time it walks, ever so slowly and cautiously, like a chameleon stalking a fly, the fishing rod vibrating madly all the while.

The angler fish of our seashore is an exception, in that most of its kith and kin live in the cold, dark depths of the ocean.

Amid the bowels of the earth,
Where dawning day does never peep,
His dwelling is.

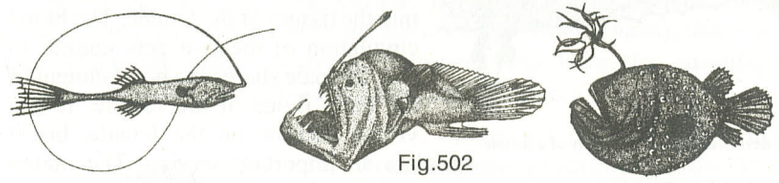
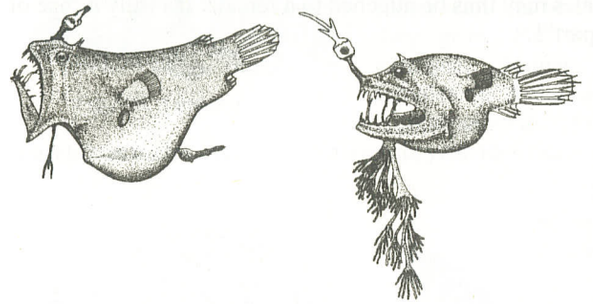


Fig.502

Some deep-sea devil-fish. Note tiny male sticking to the belly of a female which has just had a meal, as seen from its bulging belly



These deep-sea forms, called devil-fish, have the tip of their angling rod luminous to form the so-called "head lantern", with which to attract their prey in the dark. Food here is scarce so that, like the python, when they are lucky to secure a meal, they gorge themselves until their stomach is literally bursting. Some deep-sea fishes can swallow prey much bigger than themselves; the stomach just stretches like a balloon to accommodate the victim.

3rd fisherman: "Master, I marvel how fishes live in the sea".
1st fisherman: "Why, as men do a-land– the great ones eat up the little ones."

Shakespeare, in *Pericles*

Since fishes are few and far between in the vast expanse of the deep sea, a problem arises; how do the two sexes find each other in order to mate? This problem is not so great for fishes which swim together in shoals, and also for active swimmers which may meet from time to time. But for lethargic solitary fishes like devil-fish, the prospect is greatly reduced. They have, therefore, overcome the difficulty in a unique way.

** The title at first glance, appears to be misspelt, but is used here as a tribute to the author Isaac Walton who wrote a world famous book of the same name.*

Wind in the wave, gleam in the mud
The dark fire leaps along his blood;
Dateless and deathless, blind and still,
The intricate impulse works its will.

Rupert Brooke

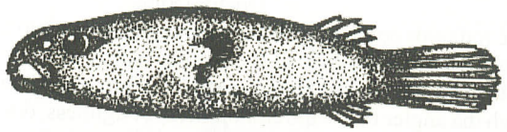


Fig.503
A male devil-fish. Note prominent jaws for clinging to a female

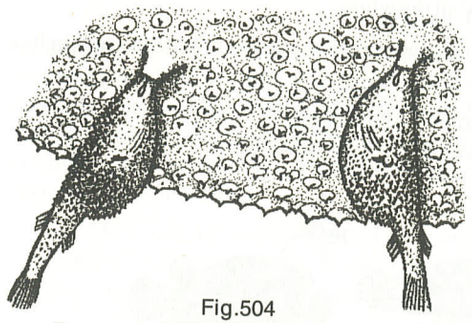
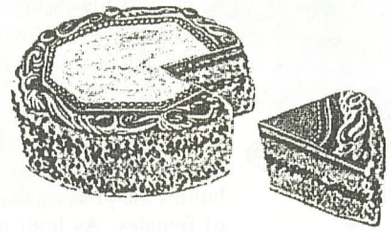


Fig.504
Two male devil-fish fused to the body of a female

The large female has a luminous head lantern, but, in the male, the first spine of the dorsal fin is modified to form a hook which, abutting against the curved lower jaw, forms an efficient pincer. The male is much smaller than the female and swims actively until it comes across a female. It then grips the female wherever it comes in contact– be it on its belly, gill-cover or the back. The male's jaws and tongue now fuse with the skin of the female and grow into the tissues of the female. The blood circulation of the two gets united, so that the male shares the nourishment of the body fluids of the female. It is a virtual parasite on the female, but it renders an important service. The male's body organs, except for the testes, degenerate. It has become a factory producing sperms. Two, three or more males may thus be attached to a female. It's truly a case of being wedded "till death do us part"!

68 Have your cake, and eat it too



A sea change into something rich and strange.

Shakespeare

The debate between the two goes on; which sex is more fortunate? Men curse their luck for having to shave every day, and envy women who have a clean chin and are spared this daily chore. And women blame the injustice of having to undergo inconvenience for half a week during each month, and of undergoing the pains of childbirth– something which, they complain, men are spared. Only the wearer knows where the shoe pinches, so the best way to have an unbiased opinion would be to change sex and find out what the other one has to endure. Unfortunately, this is not possible for us. There are other creatures, however, who have the advantages– or is it disadvantages– of changing sex during their lifetime.

Fig.505 **A grouper**

Many sea fishes and other marine animals routinely change sex as they grow. As a lot of energy has to be spent by a female in producing eggs, many fishes start life as males, and turn into females as they grow. But the reverse also happens; for example, groupers (*Epinephelus*) change from females to males as they grow. Among marine animals other than fish, giant clams (*Tridacna gigas*) start life as males. At an age of about six year, they change sex and become females.

Fig.506
Parrot fish [left]. The name comes from its hard parrot-like beak [right] used to break off pieces of coral

Parrot fish seem to be a confused lot; some start life as females and later become males, while others start life as males, but with female body colouration. (The colour pattern in the two sexes is different.) The colouration in wrasses is still more puzzling. Some wrasses have two different types of male and a number of intermediate colour phases as they change their sex. The result is that there are so many forms with different colour patterns, and unless one traces their life history as they grow, the various colour forms can mistakenly be thought to be different species.

To add to the confusion, in early life some wrasses exist entirely as females, while others have both female and non-sex-reversing males. Those that start out as primary males spawn in large groups, while those that start as females but become males in their brightly coloured terminal phase pair with a single female to spawn.

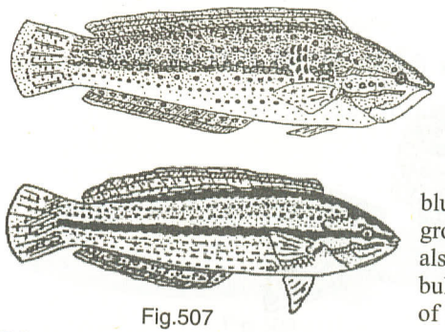


Fig.507
Colour pattern in a wrasse: (Top) Adult male (Bottom) Adult female Note female type colouration (after Kinoshita)

The moon wrasse (*Thalassoma lunare*) of our seas has a complicated love pattern. They are born as females or as primary males, both being dark green and not aggressive to others of their kind. Some of the females change into secondary males. They change their body colouration to bright blue, with bright pectoral (shoulder) fins and grow long filaments on their tail borders. They also become aggressive. Each secondary male bullies the primary males and controls a harem of females. As high tide comes in, he swims above the reef, performing loops in the water, flaunting his pectoral fins and quivering his body. The females, no longer able to resist him, rush up and mate with him. He may thus mate with eight or more females in a day. On a large reef, a secondary male is not able to control all the primary males, so that these too join in the fun while he is busy with the females.

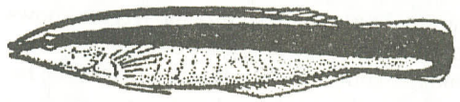


Fig.508 **Cleaner fish**

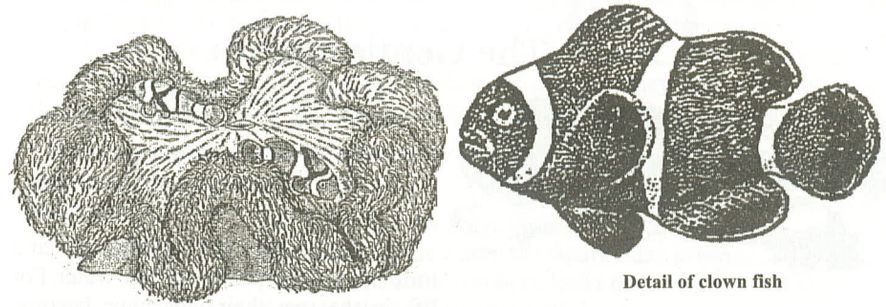
The change of sex in cleaner fish (*Labroides dimidiatus*) is more complex and is dictated by social order in the population. Within a territory is an adult male, three to six mature females and several sexually immature fish. The male–let us call him king–dominates and bullies all the females, giving a characteristic aggressive display as he tours his kingdom and comes across a female. Females dare not face up to him but have a pecking order. Female No.1–let us call her the queen–bullies all females in the territory but does not use the "male" aggressive display. Female No.2 is subdued by No.1, but bullies No.3 and down along the line.

The fun start when the king dies. If the queen is not strong, a male from outside the territory may invade it and then becomes the new king. If this does not happen, the queen, now free of the king's nagging, starts changing sex. For about half an hour after the king's death, the queen behaves normally– bullying all other females. Thereafter she starts giving the characteristic male aggressive display to all females. Within a few hours, her maleness increases, and she (now "he") starts visiting females in his territory. Within two to four days, he starts courting females and mating with them.

While "he" is beginning to change sex and become a male, a male from outside the kingdom may invade the territory. If the intruder is stronger, he will depose the new "king", who will now start changing sex, again becoming a female. But if it can face the intruder and drive him away, it will remain a male, becoming the new king.

If we see the sex organs of a female, we shall find that enclosed within the ovary is the rudiment of a testis–spermatogenic crypts filled with spermatids (the forerunners of sperms). As long as the queen was dominated by the king, the latent maleness was suppressed, but the moment the restraint was lifted her maleness increased, and in a fortnight the former queen (now "king") became a full fledged potent male.

Clown fish (*Amphiprion*) start life as males, and then become females as they grow. They swim in small groups of a dominant female and several males. As in the cleaner fish (but with reversed sex roles), she bullies all the others in her group, so that



Detail of clown fish

Fig.509 **A pair of clown fish nestling snugly among the tentacles of a sea anemone**

they remain immature or subadult males. If the dominant female dies, the largest male of the group starts bullying all the other fish in his group and, in a month, turns into a female, thereafter dominating all others.

The advantage of sequential hermaphroditism, where a fish is a male when young and then changes to a female at a later stage, lies in bigger size for reproductive success. Where there is a competition among males for the female and only the largest male successfully reproduces, there is an advantage to an animal that functions reproductively as a female when small and becomes a male when large. This is called protogynous development. Similarly, if there is a size advantage to large females (i.e., egg laying is best performed by large individuals), then there would be protandrous development, where the animal first matures as a male and then becomes female.

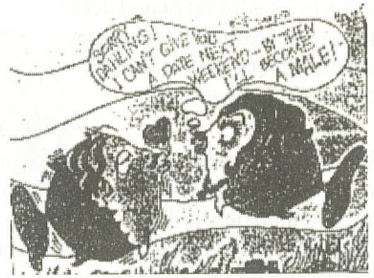


Fig.510

69 The Gentle Giants

The turtle on the naked stand
Peels to the air his pewter snout,
And rubs the sky with slotted shell
The heart's dismay turned inside out.
Laurie Lee

Sea turtles are cousins of land tortoises which opted to go into water. For life in the sea, their legs have become flattened into swimming paddles. While these are very effective for swimming, they are no good for walking. When the female visits the shore for laying eggs, she has to drag her body laboriously over the sand. The domed shell of land tortoises has become flattened and streamlined. As reptiles, they breathe air in lungs and, like us, will drown if not allowed to come up to the sea surface for a breath of fresh air. But they can remain under water for a long time. Both loggerhead and green turtles can remain submerged for 30 to 50 minutes and have survived experimental forced dives of up to five hours. During a dive, the heart beat slows down (bradycardia) and so does the metabolic rate, thereby decreasing oxygen demand. Sea turtles, unlike many marine mammals, dive with fully filled lungs, and have the capacity to extract and utilise almost all the oxygen filling the lungs. In addition, all tissues, including the heart and brain, exhibit a marked capacity to tolerate anaerobic conditions. Male turtles can be distinguished by a slightly longer tail which has a narrower base, and a concave plastron (underbelly).

The turtle lives 'twixt plated decks
Which practically conceal its sex
I think it clever of the turtle
In such a fix to be so fertile.
Ogden Nash

The eggs are round and have a thin papery shell, without lime salts. They are white and look like table tennis balls. If dropped, they will not crack (unlike birds' eggs). The temperature of the sand in which they are laid determines the sex of the baby turtle. The female takes care to bury the eggs where they will remain damp but will not get completely covered with water at high tide. A turtle embryo has to breathe, and its egg shell is porous to oxygen. As water contains much less oxygen than air, within one-half to one hour of total immersion in water, the oxyten-starved egg begins to die. Incubation at 26°-28°C will result in an all-male clutch, whereas from 31°-32°C will result in females only in loggerhead, Green and Olive Ridley Turtles. The pivotal temperature, where both sexes will occur is 29°-30°C.

The newly hatched young find their way up from the pit in which the eggs were laid, and unerringly crawl towards the sea, even if they cannot see the water as when there is a high sand dune between them and the sea. The sky looks brighter over the sea than over land due to light reflected over the water. For thousands of years, this proved them in good stead, preventing them from struggling onto land. Unfortunately, well-lit roads running just inside sandy beaches confuse them, so that they crawl away from the sea to die. Compared to the fairly huge adults, the newborns are only a few centimetres long, and fall prey to crabs, gulls, terns, kites, water monitors, dogs, jackals and boar before they reach the sea. Even there they are not safer as groupers, sharks and other fishes await their arrival.

The eggs hatch after 50 to 60 days and the young dig their way up. Even if born during daytime, in most cases they emerge at night, waiting for the sun to set. Although they cannot see the daylight while buried, they feel the heat of the sand during the day, as this is heated by the sun. As the sand cools in the evening, they notice this and emerge. However, if it rains in the day, cooling the sand, they mistake it to be night and come up.

Kipling has given the right touch of pathos and encouragement in his following poem:

Oh! hush thee, my baby, the night is behind us,
And black are the waters that sparkled so green.
The moon, o'er the combers, looks downward to find us
At rest in the hollows that rustle between.
Where billow meets billow, there soft be thy pillow;
Ah, weary wee flipperling, curl at thy ease!
The storm shall not wake thee, nor shark overtake thee,
Asleep in the arms of the slow-swinging seas.

If the hatchlings survive this ordeal, they will spend the rest of their life in the sea, and only the female will venture, years later, on land to lay her eggs.

All sea turtles are highly endangered. Apart from being caught for their meat and eggs, oil spills and the resulting tar balls foul turtles and clog the eyes and nostrils of newly hatched turtles. Pollution causes papilloma (herpes) tumours around the eyes, mouth, flippers and belly of green turtles. Boulders and tetrapods placed close together on beaches to check erosion of land block the paths of female turtles clambering up the shore to lay their eggs. And many get caught and drown in trawl nets not fitted with turtle excluder devices.

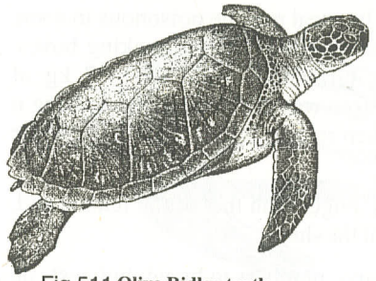


Fig.511 **Olive Ridley turtle**

Five kinds of sea turtles, all distributed widely over the world but all highly endangered species, are found in India. The commonest is the Olive Ridley turtle (*Lepidochelys olivacea*). Growing to 80 cm, they are not particular about their diet, feeding on fish, prawns, crabs, lobsters, snails, oysters and sea urchins. Unlike other turtles, females visit the shore in huge numbers to lay their eggs. This congregation for nesting is known as "arribada" a Mexican word describing the arrival to nest of vast numbers of turtles on a beach.

Mating takes place in the shallow sea near the nesting beach. After the clutch of 80 to 160 eggs (35-40 mm diameter, 35 g) is laid, mostly at night, the females fill the pit, smoothen the sand and cover it with plants such as the creeper *Ipomoea* or seaweeds. The number of nesting females is so vast that there is not enough room for eggs. Females which come later often dig up nests where eggs had been laid by previous comers on the beach. The eggs hatch after 50-60 days. The young have three distinct keels on the back.

Gahirmatha in Orissa is now on the world map as from 1,00,000 to 6,00,000 Olive Ridley Turtles nest there over a short stretch of beach within a fortnight. There are two arribadas here– a larger one in January followed by another in March. The arribadas coincide with blooms of jellyfish (hydromedusae). A hundred kilometres from

Gahirmatha, there is another arribada where a lakh turtles nest on a 3 to 4 -km stretch of beach.

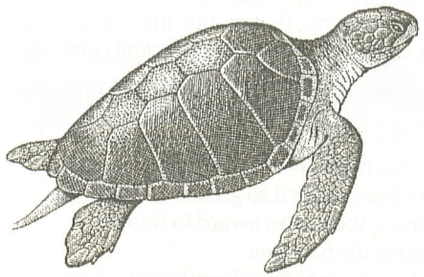


Fig.512 **Loggerhead turtle**

The loggerhead turtle (*Caretta caretta*) is often confused with the Olive Ridley turtle; it is larger (1·2 metres, weighing 110 kg) and longer. They are not seen to nest in India. They feed on hard-shelled crustaceans and molluscs. The female is sexually mature at 10-15 years. Mating is at or near the sea surface. A female may lay 4 to 5 clutches of 120 to 130 eggs (35-55 mm in diameter) at intervals of 12 to 24 days in a season at 2 to 3-year intervals. The young hatch after 50 to 80 days. It prefers beaches in temperate countries, but its largest nesting ground is on Masira Island (in Oman), where some 30,000 turtles nest in a year. The name "loggerhead" refers to the size of its head; a number of animals with large heads are called loggerheads.

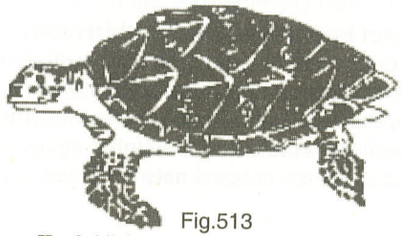


Fig.513
Hawksbill turtle. Note the overlapping scutes

The Hawksbill turtle or Carey (*Eretmochelys imbricata*) can be easily distinguished from other sea turtles by its overlapping scutes (plates) on the back. It grows to 85 cm. The jaws are strongly hooked, and there are two claws on each flipper. It feeds mainly on sponges and nests (in India) in the Andaman Islands.

Its meat may be poisonous in some seasons, but it is mainly caught for the scutes (tortoiseshell) used in making boxes, combs, bangles, rings and knicknacks. A single turtle may yield up to 7 kg of tortoiseshell. In the Maldive Islands, the earlier custom was not to kill it but to hang it upside down over a fire to remove the scutes and then release it into the sea, under the (false) belief that new scutes will form on the turtle.

The tail of an adult male hawksbill turtle is longer than that of the female and, unlike the female's tail, extends beyond the margin of the shell.

The hawksbill turtle does not assemble in large numbers to breed, but nests on beaches spread over many kilometres and over many months.

The female matures in 3-4 years and lays 75 to 180 eggs (30-35 mm diameter, 20 g) in a clutch, 2 to 4 times in a season. The young hatch in 60 days. In India, the Andaman Is. are a major nesting site (with 500 to 800 females), but in South Yemen over 10,000 of them come to nest.

The green turtle (*Chelonia mydas*) is named from its green fat. It grows to 1·4 metres, weighing 150 kg, and the adults feed on up to 4·5 kg of sea grasses and seaweeds every day. It is this turtle which is famed for turtle soup, fat, calipee (cartilage) and meat. Though it is not eaten here because it is considered an incarnation of Vishnu, its eggs are eaten, and the flippers are cut off to make shoes from the leather, for walking on sharp coral.

Nesting occurs mainly at Okha, Gulf of Mannar, Andaman Is. and Lakshadweep. Nests have been found on a few occasions at Backbay and Chowpatty beaches of Mumbai. Mating sometimes takes place on the beach, but more often in water down to 15 metres, where stacks of two to five individuals can be seen clasping each other, breaking the sea surface together for a breath of air and then remain underwater for up to half an hour.

The female comes ashore at night to lay eggs. Many a time, it comes up on the beach and then decides to go back to the sea without laying her eggs. She digs a body-pit some 25 cm wide and 50 cm deep using her fore-flippers, until she is below beach level. This may take an hour or more. Quite often, she finds the texture and wetness of the sand not to her liking, for she stops digging and goes back to the sea. If satisfied, however, she now uses her hind-flippers alternately. Even at this stage, she may decide not to lay eggs and go back to the sea. But usually she lays from 60 to 150 eggs (45 mm diameter, 35 g), 2 or 3 eggs at a time, in the oval pit, taking about 15 minutes. At this stage, she is so absorbed in her task that she can be easily approached closely. From 3 to 7 clutches of eggs, totalling 500 to 1,000 eggs, are laid at intervals of thirteen days in a season at intervals of 2 to 4 years. The 4- cm long young emerge after 8 to 11 weeks at night. Inside their nest, they cannot distinguish light from dark by seeing. They rely on the temperature of the sand for coming out. If it is above 28° C (as during daytime), the young will not come out. But rain may lower the temperature, fooling the young into emerging even during the day.

Green turtles exhibit philopatry, i.e., return to a particular regional shore– sometimes from 2,700 km away), as well as site fixity– return to a particular beach on that shore. This is after 10 to 15 years, when they are 35 cm long. They are believed to breed when they are 40 to 50 years old.

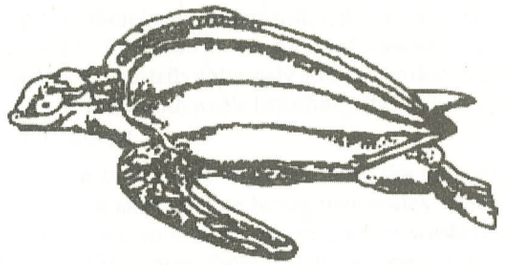


Fig.514 **Leatherback turtle**

The Leatherback turtle or Luth (*Dermochelys coriacea*) is the largest of all sea turtles, growing to 1·8 metres and weighing 450 kg; an exceptionally large specimen was 256 cm long and weighed 916 kg. Unlike other turtles which have a hard shell of keratin plates laid over rigid bone, leatherback turtles have a thick, somewhat flexible, skin-covered cartilage over a mosaic of thousands of small plate-like bones. There are seven prominent longitudinal keel-like ridges on the back, and five on the belly. The front flippers are long and clawless. It is the most aquatic of all sea turtles and is found in offshore waters. It swims long distances; a female tagged in South Guiana (South America) crossed the Atlantic Ocean and was found at Ghana (West Africa). It can dive down to 475 m and stay submerged for half an hour. Moreover, though not warm blooded, it can maintain a body temperature of 25° C in water of 8° C. This is because the arteries and veins in the flippers run close to each other so that the cold blood from the skin is warmed by the warm blood of the arteries, enabling the turtle to swim even in freezing waters.

Major nesting sites for this turtle are in Malaysia, French Guiana, Mexico and Sri Lanka. In India, it nests in the Little Andaman Is., Great Nicobar, Lakshadweep and Kerala. Lacking a hard shell, the turtles suffer from cuts and abrasions. To avoid scouring by hard sand, females often nest on muddy beaches located near river mouths, laying 100 to 200 eggs (of 50 mm diameter) in 4 to 6 clutches in a season, at intervals of 2 to 3 years. The nest is a deep, flask-shaped chamber, and once she starts laying eggs, the female is oblivious to any disturbance. The female does not lay all her eggs in one pit, but indulges in scatter nesting, thus lessening the chance of losing all her eggs through predation. The temperature during incubation determines the sex of the young–producing males only below 28·75° C and females above 29·75° C.

On hatching after 70 days, the 15 cm, 65 g young, on entering the water, immediately make a 356° turn; the significance of this is not known. The young also seem to be distasteful, as triggerfish spit them out after catching them.

Leatherback turtles feed on jellyfish. This has posed a serious problem for this species, as they mistake plastic bags floating in the sea as food items and swallow them. After several plastic bags are ingested, the gut becomes impacted and they starve to death.

70 Born to Kill

Beyond the shadow of the ship
I watched the water snakes;
They moved in tracks of shining white,
And when they rear'd, the elfish light
Fell off in hoary flakes.

Within the shadow of the ship
I watched their rich attire;
Blue, glossy green, and velvet black,
They coil'd and swam, and every track
Was a flash of golden fire.

Unlike fishes, sea snakes are cousins of terrestrial forms whose ancestors went back to a watery domain.

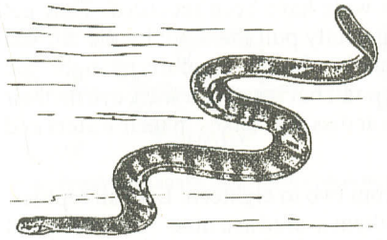


Fig.515 **Sea snake showing flattened tail**

The most primitive among sea snakes–the sea kraits (*Laticauda*) of Borneo are not very aquatic and may come up on land for a brief sojourn away from the seashore. Others, about 50 species, are found in warm seas and spend their whole life in the sea. Their tail is flattened from side to side to aid in swimming, as is the body, and the nostrils are placed on the top of the snout, so that they can breathe without exposing the whole of their head. Under water, the nostrils can be closed by valves, so that water does not enter. The nostrils are directed almost vertically upward. A pad of spongy tissue borders the nostrils anteriorly and can be distended to close them. To prevent water from entering the mouth while breathing, the glottis is plugged into the internal opening of the nasal passage.

Instead of the wide scales on the underside of land snakes which help them to slither, sea snakes have hexagonal scales which do not overlap. These cannot grip a solid surface so that sea snakes, when washed onshore, are helpless. Their flattened body and tail cause them to fall on their sides, but in water they are rapid swimmers, sculling gracefully with sinuous movements of the body. Though mostly marine, a few of them enter tidal rivers and may be found even 160 kilometres upstream.

All sea snakes are extremely venomous; their venom may be as much as eight times more deadly than a krait's. (Let me digress a little to explain the difference between venom and poison. *Venom* is injurious to us when it is injected or otherwise introduced into our blood usually by a jab from a sharp -pointed hollow device like a snake's fang. *Poison* causes harm only when eaten or drunk and entering our digestive system. Thus, sea snakes are venomous, not poisonous, though many persons wrongly use the latter word. If you have no cuts in the mouth, and no ulcers, you can safely swallow snake venom.) Their venom is similar in reaction to cobra venom; the nervous system gets paralysed, breathing fails and the victim dies. And the venom is present right from birth, so that even newly born sea snakes can kill. But, fortunately for us, almost all sea snakes (see exception below) are very docile, unlike the vicious venomous land snakes, and rarely attempt to bite. The Asiatic file-snake (*Chersydrus granulatus*) is found in

estuaries where the sea water is diluted; it is not venomous.

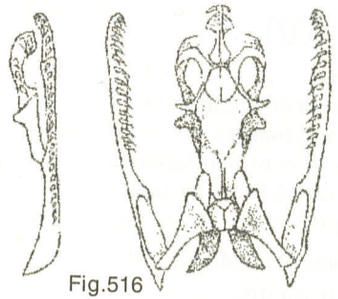


Fig.516

Skull (top view) and upper jaw of banded sea snake (*Enhydrina schistosa*) showing two large poison fangs and row of smaller teeth behind.

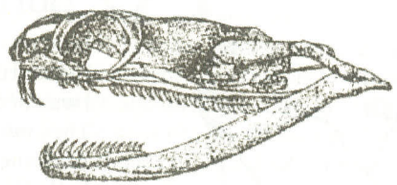


Fig.517

Skull of sea krait (*Laticauda colubrina*) showing fangs . (After Boulenger),

Sea snakes are fond of basking on the sea surface, and sometimes congregate in hundreds. These snakes are thought to gather together for mating, and huge swarms stretching for 27 kilometres and three kilometres wide have been recorded. They get entangled in fishermen's nets, but the latter nonchalantly pull them out by the tail and throw them back into the sea. I, too, have regularly (though carefully) caught and handled them at our Aquarium, lifting them by their tail but keeping a wary eye on their head. This fascinates westerners who do not come across sea snakes in their waters and have an awe born out of ignorance.

Sea snakes give birth to live young, varying from two to eighteen. Like all reptiles, the males have two mating organs, but only one of them is used at a time. And I have had the rarest of rare opportunities to witness a pair of *Enhydrina schistosa* mating in captivity. The male had twisted the hind portion of its body tightly around that of the female, making two and a half turns of its body in tight coils around the female. The tail as well as the front part of the body were quite separate. The region around the vent in the female had become quite turgid, and fishes (*Caranx*) kept in the tank frequently nibbled at the skin in this region. This, however, did not disturb the snakes in the least, as they lay at the bottom of the tank. From time to time both the snakes simultaneously rose, still tightly twisted, slowly up to the surface of the water for a breath of air. Mating was first observed at 12·30 p.m., and the snakes were seen to have separated by 7·30 p.m. the same day.

Like all snakes, sea snakes too have only one long lung extending right upto the tail. There is confusion as some people speak of lungs of a snake. Some snakes do have a vestigial left lung, but this is rare. The confusion arises because the right lung is divided into the vascular and saccular lungs with the vascular lung further subdivided into a bronchial and the tracheal lungs. But having only one lung does not deter them from diving down to 50 metres, and remaining submerged for over 3·5 hours. They can breathe (partly) through their skin, which absorbs one-third of the oxygen required, and also removes 90% of the carbon dioxide. Now how are these observations made? Experts during the Galathea Deep Sea Expedition put sea snakes in sealed containers and lowered into the sea. When hauled up after two hours, the snakes were found to be alive, and not at all distressed. And other experts attached ultrasonic pressure transmitters to snakes and released them, to record the pulses sent up.

Experts, did I say? Well, there are experts and experts. Our international airline once advertised for a post of "animal handler". Many kinds of pet, zoo or wild animals, birds and fish are sent by air. Sometimes, they have to remain at an airport while awaiting being transshipped by another plane. Their cage may have to be cleaned, food and drinking water to be given to them or oxygen to be filled in the bags holding them. This is all done by the animal handler, who is an expert at his job.

A person from one of the largest dairies in India applied for the job. Since he worked in a dairy, it was assumed that he was most accustomed to handling buffaloes and cattle, and was asked questions about these animals during his interview. He fumbled a lot, so one of the interviewers asked him which section of the dairy he worked in. It turned out that he was working in the bottle-washing section!

Mechanically minded scientists have made a computerised robot snake with 30 joints which can move like a sidewinder snake. It is used for exploring under the debris of crashed buildings where sniffer dogs cannot go in. They hope to make a miniature model that can be swallowed to find out what is the condition inside our stomach and intestine.

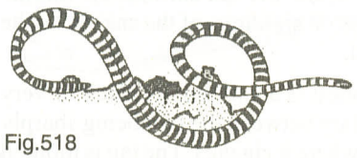


Fig.518

Blue Banded sea snake (*Hydrophis cyanocinctus*)

Some sea snakes may grow to three metres with their body as thick as one's forearm, but most are only 1¼ metres long. And females are usually larger than males. Thus an adult male blue-banded sea snake (*Hydrophis cyanocinctus*), one of our commonest sea snakes, is 150 cm long, of which the tail is 13 cm, while the female is 188 cm long. This snake can be distinguished by the central horizontal keel on each scale. The number of bands in Indian forms varies from 50 to 75, but may be as few as 38 (in Borneo) or as many as 85 (Gulf of Thailand). *Hydrophis phipsoni*, described from Mumbai by Murray in 1887, is an aberrant form of *H. cyanocinctus* where the bands are confined to the neck region and the back has a dark stripe.

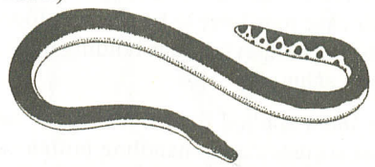
Fig.519

Snake eel (*Pisodonophis boro*) is the favourite food of sea snakes

Sea snakes feed on thin long fish, such as the snake eel (*Pisodonophis boro*) or *Trypauchen vagina*. In captivity, most of them refuse any food, and have to be fed forcibly on beaten raw eggs, by pushing a soft rubber catheter attached to an ear syringe down their throat. And they are not bothered when swallowing fish with long sharp spines. The spines pierce the snake's gut and body-wall and pass out to the exterior without causing any inconvenience or injury. Snakes of the genera *Aipysurus* and *Emydocephalus* consume fish eggs as their staple diet.

Most sea snakes moult their skin every four to five months, and have a banded pattern, with dark grey rings alternating with lighter ones. The dark portions are broader on the back, narrowing to a 'V' as they go down to the belly. These markings are most vivid in the young or in freshly moulted snakes,.disappearing as they age. The dark bands first fade out ventrally, but remain on the upper side and back. The head may also become paler with age. The moulted skin is sloughed in bits and patches. Stalked barnacles grow on the skin of old snakes, but do not appear to disturb them. And all sea snakes have a salt gland in the floor of the mouth surrounding the tongue sheath, and the salt secreted

by it is expelled when the tongue is extruded. This helps them to get rid of extra salt ingested with (or in) food. (Turtles have salt glands in the eyes, and marine lizards in the nose.)



Yellow-bellied sea snake (*Pelamis platurus*).

The yellow-bellied sea snake (*Pelamis platurus*) is the most widely distributed sea snake, ranging from East Africa, across the Indian and Pacific Oceans, all the way to the west coast of Mexico and Panama. Their geographic range would be wider, were it not for the cold currents of Namibia and western South America which prevent its passage into the eastern Atlantic Ocean and south of the 5° S latitude on South America's western seacoast. Similarly, unsuitable salinity has excluded it from the Red Sea and in reaching the Caribbean islands through the Panama Canal. It is smaller, males being 72 cm long, of which the tail is 8 cm, while the female may be 88 cm. It is more aggressive than other sea snakes. It is found only in the sea and does not frequent river mouths. On the contrary, it may be seen hundreds of kilometres away from land, thousands of them swimming in a solid mass on the surface. They are also very good divers and spend some 80% of the time below the sea surface. As marine biologists base their calculations of snake populations on sightings of the snakes on the surface, their numbers are likely to be underestimated.

Many colour variations exist, but the commonest is a continuous black or very dark brown above and a yellow underside, the boundary between the two being sharply defined. This line runs straight till just before the tail where it zigzags. The tail is mottled with bars and spots of black and yellow. This is the so-called *bicolor* strain and is the one found off Mumbai. *Pelamis* moults every fortnight.

As sea snakes are so venomous, one would expect that they would have no enemies. But sharks eat them, and so do sea eagles.

Eye to eye and head to head …
This shall end when one is dead.

Rudyard Kipling *RIKKI-TIKKI-TAVI*

I have come across a buoy in the harbour with its top covered with the skin and bones of sea snakes. The bird of prey would sit leisurely on the buoy and eat the insides, leaving the rest. And people also eat them in the Philippines and in Hainan, where they are esteemed.

We hardly come across dead animals in the sea, but I have observed that sea snakes at our Aquarium invariably die curled up on the tank bottom like a tightly wound watch spring, with the head near the centre of the coils.

Fig.521

A mediaeval illustration showing a "sea serpent" spouting fire.

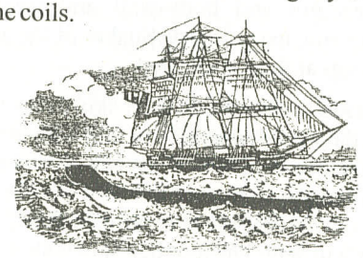
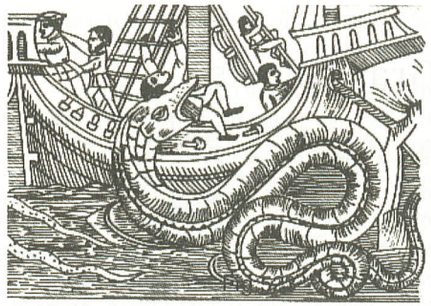


Fig.522

A later illustration showing a huge sea serpent swimming past a sailing ship.



A mythical sea serpent 60 meters long, 6m around, with a mane of hair 60 cm long on its neck, scales on its body and small fiery eyes.

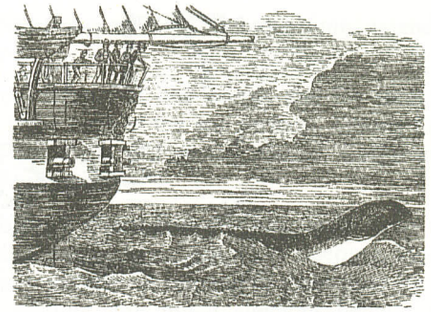


Fig.524

A later illustration showing a huge sea serpent swimming past a sailing ship

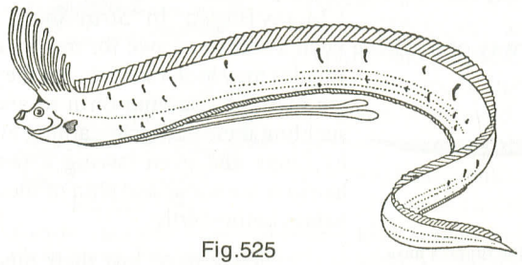


Fig.525

The oar fish *(Regalaceus russellii)* is often mistaken as a sea serpent

Tales of great sea serpents have played a large part in folklore. But these are myths, based on far away sightings in fog and bad weather of oar-fish, giant eels, the tentacles of giant squids, whales and porpoises. The oarfish (*Regalaceus russellii*), named for the paddle-like expansions at the ends of its long pelvic fins, is the longest of bony fish, reaching a length of over 15 metres. It lives at depths of 210 metres and has been seen swimming in a vertical position at that depth. It feeds on soft-bodied, large plankton such as salps and ctenophores. In northern Europe, it is called king-of-the-herrings, as it is seen at the beginning of the herring runs. For the same reason, northwest Pacific American Indians call it king-of-the-salmon. The Japanese have a more fascinating name for it– cock-of-the-palace-under-the-sea, referring to the rayed flame-coloured crest that the fish can raise and lower like a rooster's comb. It is rarely seen, and often mistaken as a "sea-serpent" because of its length.

71 The Gray Ghosts

Led by a grim grisly monster grey,
In the distance, lo! they vanish away
To be followed soon by numbers more;
There! you can count them by the score.
J. Moray Brown In "*Stray Sport*"

Their giant size and unique way of life have been a source of awe for mankind Whales may look like fish, but they are mammals, giving birth to and suckling their young, breathing air by lungs and even having a few hairs on the snout and chin of their babies before birth.

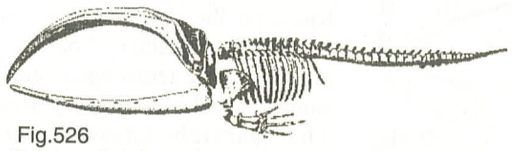


Fig.526
Skeleton of a baleen whale. The bones of the flippers have a remarkable resemblance to those of the human hand

Skeleton of a sperm whale. Note the vestigial pelvic (hip) bones. (Original drawings from British Museum publication)

They have lost their hind limbs (legs), but an X-ray of their flippers shows a remarkable resemblance to our hands. (Some whales do have vestigial pelvic bones which support the reproductive organs.) While fishes have a vertical fin, whales have horizontal flukes which move up and down to push the whale forward; these have no bony support. Whales have increased their swimming efficiency by getting rid of a fur coat, but, as most of them live in cold seas, they keep warm by having a thick layer of fatty connective tissue below the skin, called blubber. This is over 30 cm thick in the rorquals, and even thicker in the right and sperm whales. The blubber is so efficient an insulation against cold, that, in the event of a whale getting stranded on a shore, its body gets heated by the sun and cooked. Their bones are spongy and light.

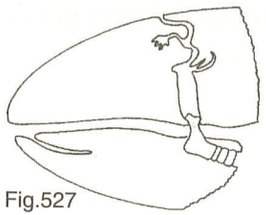


Fig.527
Whales, dolphins and porpoises can breathe even when their mouth is open, as a projection from the windpipe plugs the blow hole tube

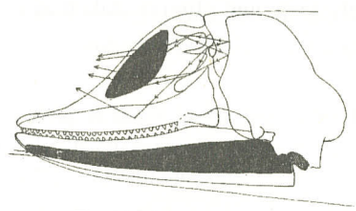


Fig.528 Echo-location in dolphins
(See Chapter 73)

Their nostrils have shifted to the top of the head to form "blowholes", so that they can breathe without exposing their body above water and can even feed with their mouth open without water getting into the lungs. The upper end of the windpipe projects into the inner end of the blowhole pipe (inner nostrils), and sometimes extends as a long spout fitting inside the blowhole pipe.

All Cetaceans (whales and dolphins) sleep, but less deeply and for shorter periods of time than humans, typically in short naps at the sea surface. Among the species "caught napping" are pilot, gray, fin, right and sperm whales. Collisions between ships and slumbering whales have been reported.

Since all marine mammals must breathe every few minutes, their sleep is adapted for regular surfacing, and they rarely are completely still while sleeping. Most marine mammals do not sleep in regular daily patterns. A number of them have been observed continuously for several days without any noted sleeping behaviour. Humpback whales apparently do not sleep at all during their long breeding migrations.

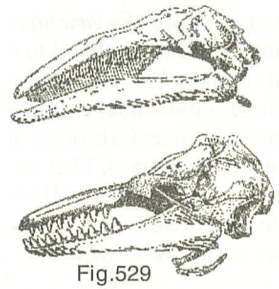


Fig.529
Skulls of baleen whale (upper) and toothed whales (lower) . Note the baleen plates

The Order Cetacea which comprises whales, is divided into two suborders–the baleen or whalebone whales (*Mysticeti*) and the toothed whales (including dolphins and porpoises) (*Odontoceti*). The baleen whales do not have teeth. Instead, they have 200 to 300 flexible flat plates suspended from the roof of the mouth. Their edges are frayed into bristles, and the plates act as sieves to filter out small planktonic food such as krill (*Euphausia*–a prawn-like animal), pteropods (swimming molluscs also known as sea butterflies) and copepods. The small size of the food is made up by their enormous numbers. To feed, all that the whale has to do is to swim through a large shoal of these creatures with its mouth open, close its mouth and raise its tongue to throw out the sea water between its lips and swallow the mass of food.

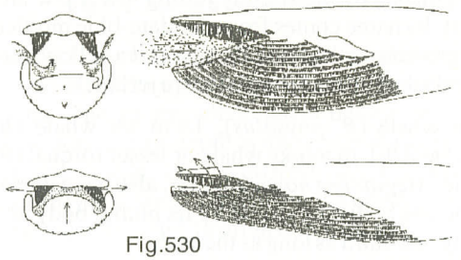


Fig.530
Mode of feeding in a baleen whale . In the upper pictures, the whale has opened its mouth, thereby increasing its capacity, so that water (along with food) flows in. Lower pictures show the whale closing its mouth; the tongue squeezes water out

All baleen whales have two blowholes, and the females are larger than males.

Nine species of whales are classed among the great whales; of these, eight are considered endangered. Their maximum size and estimated populations are: Family Balaenidae: bow-headed whales 3,000 to 4,000, 19.8 metres (65 feet); right whales 3,500, 18 m (60 ft.). Family Balaenopteridae: blue whales 7,500 to 15,000, 33.5 m (110 ft.); fin whales 1,00,000 to 1,20,000, 26.8 m (88 ft.); sei whales 35,000 to 55,000, 19.8 m (65 ft.); humpback whales 9,000 to 10,000, 18.3 m (60 ft.). Family Eschrictiidae: gray whales 13,500 to 19,000, 15.2 m (50 ft.). Family Physeteridae: sperm whale 1 million, 18.9 m (62 ft.).

The ninth species, Bryde's whale belongs to the family Balaenopteridae. It is not considered to be endangered, as its population is estimated to be 20,000 or so.

Fig.531
Six of the largest whales; compare size with elephant. From top, humpback, sei,sperm,right,fin and blue whale

The 18·3-metre long Greenland right whale or bowhead (*Balaena mysticetus*), 18-m black or Biscay right whale (*Balaena glacialis*) and the 6-m pygmy right whale (*Caperea marginata*) are so called because they are the "right" ones for hunting; they remain afloat after being harpooned and killed, and are thus easy to retrieve, whereas the others sink after death, to be lost to the whaler. The first two can be distinguished by the absence of a dorsal fin and the strongly arched jaws.

The 13·7-m gray whale (*Eschrichtius gibbosus*) too has no dorsal fin, but has 2 to 4 short furrows on its throat. It feeds during summer in the Arctic seas but comes down to Korea and the lagoons of Lower California in winter to calve (give birth to young). They are very friendly and even allow themselves to be stroked, hence they are favourites of tourists and whale-watchers.

The rorquals comprise the finback whales (*Balaenoptera*) and the humpback whales (*Megaptera*). (The word "rorqual" comes from the Norwegian *rorhval*, meaning furrow– a reference to the whale's numerous throat grooves.) Among the former, the blue whale (*Balaenoptera musculus*) is the largest among whales and the largest animal ever to have lived on Earth (being larger than even the largest dinosaurs). It grows to 31 m and weighs 152 tons, and can be distinguished by the slightly jutting lower jaw and numerous (80 to 100) grooves on its throat. Its name comes from the slate-blue mottled colour of the body. A thin film of diatoms growing on its skin often gives it a yellow hue, hence it is also then called sulphur bottomed whale. Its baleen plates are jet black.

Other rorquals are the 26-m fin whale (*B. physalus*), 18-m sei whale (*B. borealis*), 15·2-m Bryde's whale (*B. edeni*) and 9·1-m minke whale or lesser rorqual (*B. acutorostrata*). The 15-m humpback whale (*Megaptera novaeangliae*) also has a dorsal fin and grooves on the throat, but it can be easily distinguished by its plump body and extraordinarily long, narrow flippers nearly one-third as long as the body.

Many whales also "sing". The best known and recorded song is of the humpback whale *(Megaptera novaeangliae*). It normally lasts 8 to 20 minutes or longer. It usually consists of 4 to 8 ordered themes which, in turn, are made up of repeated units or groups of units called phrases. The unit may sound like meaningless groans, whistles, chirps or grunts to the uninitiated. They actually comprise the highly structured song which may be repeated many times during a single song session that may last for hours. (One whale was heard to sing continuously for 22- hours.) The song can be heard from up to 32 kilometres away.

The toothed whales (*Odontoceti*) have a single blowhole, and males are larger than females. Almost all of them have asymmetrical skulls.

The sperm whale (*Physeter catodon*) is the giant among toothed whales, males growing to (average) 15 m long and weighing 45 tons; females are 11 m long and weigh 20 tons. The name comes from spermaceti–a clear liquid found in its huge head which, on cooling, solidifies into a waxy substance looking like milt. The corrugated, shrivelled looking skin is dark grey with patches of white; these increase in size with age so that old males may be entirely white. It must have been one such which Herman Melville vividly described as Moby Dick. The huge squarish bulbous head is almost one-third as long as the body. Below it is the ridiculously small, slender tongue-like lower jaw. On it are about 50 conical teeth; the upper jaw has only tiny vestigial teeth. Each tooth can weigh as much as a kilogram. The flippers are short and stubby, but the broad tail flukes are larger than in other whales.

While baleen whales dive down normally to 91 m and can go down to 457 m when frightened, sperm whales can go down much lower; one was found entangled in a submarine cable at 2,200 m. And they can remain submerged for over an hour. (Rorquals can remain down for only 40 minutes.) While diving, the heart beat is significantly reduced; in a white whale, the normal rate of 30 beats per minute fell to 16. They can attain speeds of 40 km per hour when swimming, though the normal speed is 6 km per hour.

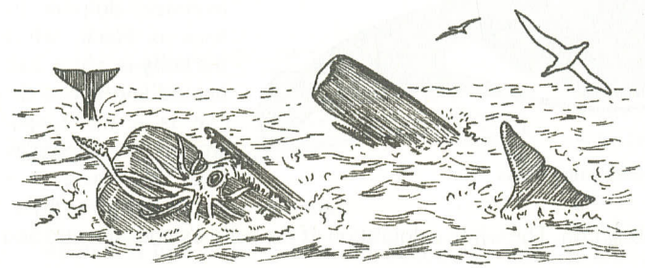


Fig.532 **Sperm whales feeding on giant squid**

Sperm whales feed mainly on squid, but also on fish and jellyfish. They may eat a ton a day, and are known to feed continuously for 30 hours. Veritable battles must be taking place between giant squid known as kraken and sperm whales in the deep. They bear scars and marks of suckers (of the squid) up to 20 cm in diameter; these must have been made by squid 45 m long. The sperm whale has a unique buoyancy device which enables it to hold its position at any depth without having to swim. When it dives, it fills its long nasal passages with water at different depths, thereby cooling part of the liquid spermaceti to solidify into wax. The greater the depth to which it dives, the colder the water gets, and the more the solidification into wax, thereby increasing the whale's buoyancy.

Sperm whales are gregarious animals, the males forming harems. While adult males may be found even in polar regions, females and young are restricted to warmer seas between 40° N and S latitudes, living in groups led by an old female. Males fight over females, locking their jaws and rolling over and over on the sea surface until the weaker one gives up. The 4-m long calf is born after a gestation period of 14 to 16 months. The mother remains vertical while the calf is born, tail first. The other females of the group surround the mother and nudge the newly born calf to the sea surface. The calf suckles for 1 to 2 years, even though it may have started feeding on squid. A female breeds once every 4 to 6 years.

Though sperm whales are so huge, they are vulnerable to attack by killer whales. Normally they utter clicking sounds one– click per second when feeding, but these can go up to 80 per second. But when attacked, they remain silent and herd closer together.

They form a circle with their heads outward.

An expensive substance called ambergris is obtained from the intestines of sperm whales; more of this in a following chapter.

At least one sperm whale has been found stranded on Indian coasts. The pygmy sperm whale (*Kogia breviceps*), growing to only 3½ m. has a worldwide distribution in tropical and temperate seas, and is occasionally found stranded on Indian shores.

Its faeces (stools), as also seen in the blue whale, are of a bloody red colour. This is due to its food source. It feeds on squids. These, in turn, feed on krill and other prey which, in their turn, feed on diatoms. These contain a pigment called carotene, and it is this pigment which makes the faeces red. Blue whales, which feed on krill, also have their faeces red for the same reason. Patches of red faecal matter associated with a whale have often been mistaken as blood by untrained observers, who think that the whale is suffering from an open wound.

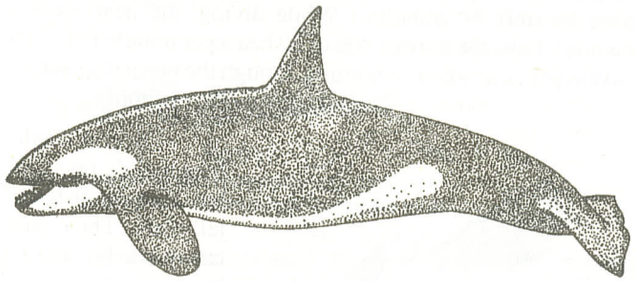


Fig.533 **Killer whale**

The killer whale (*Orcinus orca*) is actually an oversized dolphin. Its back is black, while the belly is white. Just behind and above the eye is a white spot shaped like a convex lens, and there is a dark grey saddle-shaped area behind the dorsal fin. The white colouration of the belly extends upward and backward at the tail end.

As with all toothed whales, there is a huge difference in size between the sexes. While the male is 8 m long and weighs six tons, the female is only 7 m and weighs 4 tons. Moreover, while the tall, straight dorsal fin of the male is 2 m high, that of the female is curved like a shark's dorsal fin and only 30 to 60 cm high.

Killer whales swim together in pods (groups) of from 2 or 3 to as many as 25. The smallest pod consists of a mature female, her calf (if still alive) and her mother. These may combine for a short period to form superpods (clans). Found in all seas, they prefer colder water and near the shore. They can swim at 50 km per hour, and dive down for four to eight minutes, but do not cover long distances underwater (only up to 150 m). Males live up to 29 years; females live longer– up to 50 years, but they stop breeding at 40 years, giving birth to five or six young during a lifetime. The 2-m long calf is born after a gestation period of 16 months.

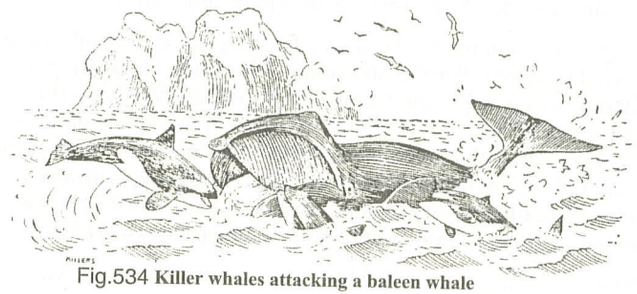


Fig.534 **Killer whales attacking a baleen whale**

Like wolves, killer whales hunt in packs, their prey being (preferably) warm-blooded animals like sea birds, dolphins, porpoises, seals, walruses, polar bears, penguins and even blue whales. They are equipped with 10 to 12·5 cm long, conical, pointed teeth on each side of both the jaws. Small prey is swallowed whole, larger ones being torn apart. They seek their prey by standing vertically in the water and raising their heads out of the water. To overpower blue whales, some of the killer whales catch hold of its tail, while others hold on to its head and bite the lips, forcing it to open its mouth, when the killer whales bite off the tongue and feed on it. Their appetite is voracious; one animal had the remains of 13 porpoises and 14 seals in its stomach. They may tip over an ice floe to push off a seal, but accounts of them attacking men in a similar manner have been found to be baseless, as is now evident from experiences of trainers in oceanariums, who play with these gentle creatures and even place their heads inside a killer whale's mouth. Earlier accounts are based on Captain Scott's diary, where he wrote that, while Mr. Ponting of the Antarctic *Terra Nova* Expedition was standing on an ice floe and taking photographs, the floe heaved up and was broken into fragments. As he fled to safety, he heard booming sounds, which he attributed to killer whales rising under the ice and striking it with their backs. In those days, men on polar expeditions wore white fur-skin dresses as a protection against the bitter cold, and could be easily mistaken for seals when crouching or sitting.

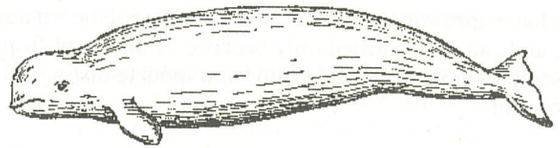


Fig.535 **Beluga or white whale**

The circumpolar, 5½ metre long Beluga or white whale (*Delphinaptenis leucas*) starts life with a dark gray body; this turns gradually to a yellow shade and, when it is four to five years old, becomes white. It lacks a dorsal fin. It ascends rivers to over 1,000 km.

Fig.536 **Narwhal (left) and the mythical unicorn (right)**

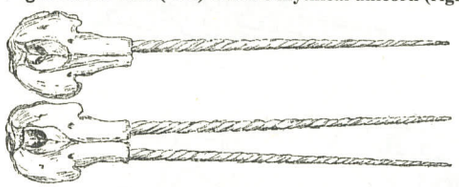


Fig.537 **The tusks of Narwhals**

The narwhal (*Monodon monoceros*) looks like a beluga and grows to the same length. But the male has a 2·44 m long spirally twisted tusk, which is actually the highly elongated left tooth of the upper jaw, projecting forward from its snout. The right tooth is usually small but, sometimes the right tooth is also elongated, so that the animal now has two tusks. Rudimentary teeth are present in females, but they do not form tusks. The origin of the mythical animal– the unicorn is said to be the narwhal.

For many centuries people talked of a mysterious creature looking like a horse but with a single, spirally twisted horn (called the alicorn) growing out of its forehead. The Roman soldier-naturalist Pliny considered it a rather everyday creature of India and more distant places; he probably confused it with the rhinoceros. The horns of both of them were considered to possess magical and medicinal properties, such as aphrodisiacs; when powdered and taken with a drink, or when a part of the hollow horn was used as a cup, it could serve as an antidote to any poison.

The alicorn was highly prized. After his second voyage to the Canadian Arctic in 1577, Martin Frobisher gave to Queen Elizabeth-I a unicorn tusk valued at £ 100,000/-.

About 800 years ago, sailors and fishermen in Arctic seas began to find long, straight ivory horns on the shores of remote islands, but it was not until the 18th century that it became more generally known as the tusk of a whale.

Sailors in the good old days put to sea prepared to be attacked by fearsome beasts and they took with them an imagination sufficient to endow the most inoffensive creature with destructive powers. And whales, with their huge size, were especially dreaded. Their nautical charts were embellished with illustrations that are more reminiscent of land animals. Thus the sea horse was depicted with the head of a horse and forelimbs with hooves.

Depicted here are some whales appearing on a chart of 1585. Some of the whales have heads resembling a boar's, and can be identified only because of the spout from their blow-hole. The narwhal resembles a swordfish but again has a spout to distinguish it. Their descriptions are worth reading.

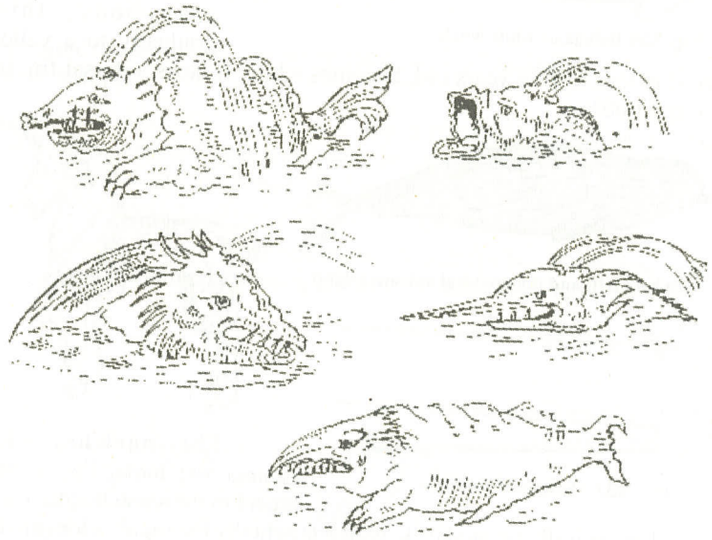


Fig.538 **Monsters based on the sightings of whales (After Hynes, 1585)**

My encounter with a whale was a tragi-comic event. It happened this way. I was asked to go to a place some kilometres north of Mumbai, identify a dead whale stranded there, take its measurements and photograph it. As I had no camera of my own, I persuaded a friend of mine to accompany me with his camera; all his expenses would be paid by the government. He was a trifle reluctant. Knowing that he was a gourmand, I tempted him with an offer of a sumptuous lunch at our place of visit.

In the train, we got talking to our co-passengers, and were advised that it would be better if we got down one station prior to the one we had intended to alight. It would be nearer, and a one-hour journey by bus would take us to a small village, from where the sea shore was only a stone's throw away.

Everything went fine. We located the whale, and in half an hour we had finished our task. I was glad that we could return earlier than planned. We went back to the village where we learnt, to our shock, that only one bus plied there every day– the one by which we had come. And this bus had just left; it would come back only tomorrow.

As we had no intention to stay there overnight, a kind villager advised us to go to another village 27 km away, from where a bus starting at 2 p.m. would take us to another railway station, from where we could return to Mumbai. He added as an afterthought, that if we did not walk on the road but along the seashore, it would be only 18 km away.

A hurried calculation revealed that there was no time for breakfast, and even then we would have to walk fast to reach the place in time to catch the bus. So off we went. The villager had not told us that our short-cut would entail our wading in knee-deep to thigh-deep water at several places where there were small creeks.

The sun was hot, and we huffed and puffed, my portly friend grumbling that I had spoilt his day. Finally we were two kilometres away from our destination, but there was less than half an hour to make it. So I told my friend that we will have to run the rest of the way if he wanted to avoid missing the bus and to walk another 20 km. I still recollect him running behind me, muttering aloud that I had promised him a sumptuous lunch, and here he was with an empty stomach, trudging and running, panting like an ordinary coolie. Luckily, we made it just in time to have a quick bite at a ramshackle inn and board the bus. It was a whale which my friend will not forget the rest of his life!

72 The ... that lays the Golden Egg

One of the most cherished items that a beachcomber hopes to find on the seashore is a foul smelling ungainly lump looking like candle-wax. People have somehow got a highly exaggerated idea of its value. It is ambergris, now known to be a product of (in)digestion from sperm whales. This substance has been known for ages, but its source was always a mystery. Natives of the Maldive Islands, wrote Barbosa, believed that "there are certain great fowls which alight on the cliffs and rocks of the sea, and there drop this ambergris, where it is tanned and softened by the wind, the sun and the rain, and pieces both great and small are torn by storms and tempests and fall into the sea until they are found washed up on the strand or swallowed by whales." Even though the ancients found ambergris in whales, they believed that it was not produced by this mammal which only ate it when coming across it in the sea. Others believed that birds of Madagascar produced dung which melted in the sun and flowed into the sea. Even trees, seals, crocodiles and bees were thought to produce it.

Fig.539 Sperm whale (*Physeter catodon*)

Ambergris is originally found as lumps in the intestines of sperm whales (*Physeter catodon*), also known as cachelot. Inside the lumps are usually embedded the parrot-like beaks of squid or cuttlefish which are the food of the sperm whale. When ejected with the faeces, ambergris looks like round stones or pebbles, dark to almost black, sticky but not heavy. As it floats in the sea, it becomes lighter in colour, from dark brown through pale golden to chalky white. Its smell also changes– first to fishy to earthy or musky.

Though normally found as small pieces, larger chunks of ambergris have occasionally been found. A huge piece 198 cm long and 76 cm wide, weighing 420 g was obtained from a 15-metre sperm whale in 1953. The largest piece so far is thought to be one of 445 kg reported by the Dutch East India Company in 1880.

Once upon a time, ambergris was worth its weight in gold. As far as a thousand years back, it was classified with gold and slaves from Maghreb (northern Africa), as a valuable trade item. Even as late as the 17th century, the East India Company paid 17 shillings for an ounce (28 g). A 24-kg piece found in Scotland was sold for $42,750. In 1956, a piece weighing 69 kg fetched $20,000, and a piece over 90 kg for £500 in 1955. Today's prices are much less. Ambergris was used for several purposes. In India, it was thought to have the power to assist women suffering from childbirth complications. In Iran it, along with musk, was added to sweetmeats and confections as an aphrodisiac. The Chinese, who called it *lung yen* (dragon's saliva) believed that it helped in the formation of bone marrow and milt. Others thought that it extended life span. It was also a remedy for typhoid, epilepsy, apoplexy, headache, rabies diarrhoea, asthma, tuberculosis, as a diuretic and even to dispel ghosts and exorcise evil spirits in people who were possessed by the devil! The Cantonese made it into pills which were "everlasting and could be chewed for years without diminishing in size."

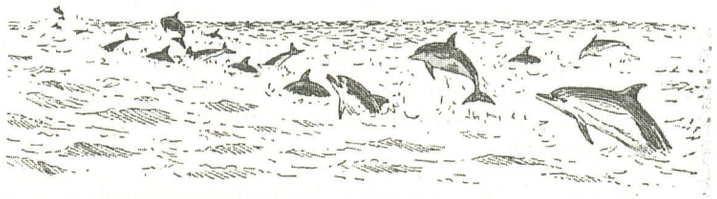
Today, ambergris is used as a fixative in the finest and most expensive perfumes. While musk gives perfume maximum diffusive power, ambergris adds nothing to the smell but gives it a long duration against evaporation and imparts a subtle velvetiness. While a cheap perfume (without ambergris) may last only for days, one with it will last for months.

Amberin– the starting material for ambergris–is actually present in squid, which are then eaten by sperm whales. It forms white, needle-like crystals. In the presence of copper or vanadium, and on exposure to air, sea water and sunlight amberin changes to ambergris.

Synthetic ambergris is now made from the intermediate constituents, gamma-dihydroionone and ambreinolide. The former gives it the characteristic faint odour of ambergris, while the latter is responsible for its fixative qualities. It is only one-ninth as expensive as natural ambergris, and is marketed as "Ambropur" by the Swiss, and as "Grisambrol" by the Germans.

Since most of the so-called ambergris collected by beachcombers on our shores turns out to be tar balls, wax, or even pieces of rubber slippers, it is desirable to test these pieces. Ambergris is insoluble in water, is light in weight (specific gravity 0·78 to 0·98), so it floats on water. It melts in hot (65° C) water. If we heat a wire over a flame for 15 seconds and press it on ambergris, a dark brown to black opaque, resinous fluid will form around the wire and appear to boil. (Wax will give a clear liquid when thus treated.) If the melted material on the wire is touched, it will leave sticky, tar-like threads sticking to the finger. (Wax will coat the finger or take its impression.) On cooling, the ambergris string will look shiny like dark brown or black enamel. When the wire with this material is again placed in a flame, ambergris will first emit white fumes smelling of (cold) ambergris, and then burn with a bright flame. (Wax does not emit fumes until it is about to burn, and then has a hot-wax or acrid smell.) After the burning flame is extinguished, ambergris will smell like burning rubber.

73 Neither Fish nor Fowl (the adorable, intelligent dolphins)



What pleasing wonders charm the sailor's sight
When calms the Dolphins to their sports invite.
Oppian

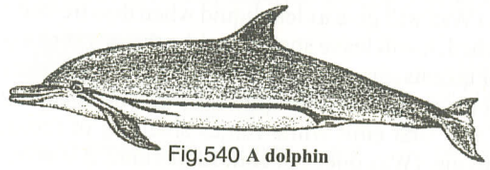


Fig.540 **A dolphin**

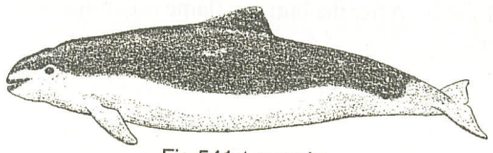


Fig.541 **A porpoise**

Dolphins and porpoises are diminutive cousins of whales. They are normally 2·4 m long, and can be distinguished by the single crescentic blowhole having its forward margin concave. Dolphins have a 15-cm long narrow snout or "beak" (except Risso's dolphin), provided with 40 to 50 peg-like teeth in both the jaws. In most dolphins, the hind border of the dorsal fin is curved in an arc. Porpoises are beakless and have spade-shaped teeth. The dorsal fin is absent; if present, it is triangular (except in Burmeister's porpoise).

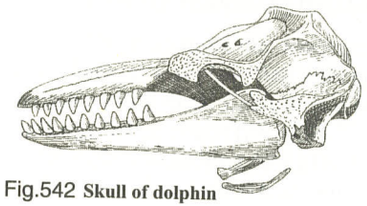


Fig.542 **Skull of dolphin**

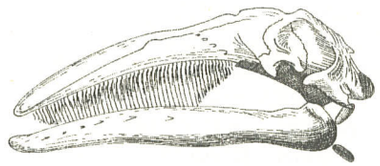


Fig.543 **Skull of porpoise**

Dolphins are fast swimmers and can effortlessly keep pace with a ship sailing at 25 knots. They are carnivorous, their prey consisting of fish and squid. Being mammals, they are warm blooded and have a 27-mm thick layer of blubber. Unlike whales, they frequent warm seas. They get rid of excess body heat, generated by their fast swimming, by a mechanism using the principle of counter-current heat, which is also used by engineers in power plants. In their body are masses of small, parallel contiguous arteries and veins arranged alternately and dividing into a large number of intricately twisted branches forming a network of communicating tubes. It is called *rete mirabele* (meaning "wonderful net"). The warm blood in the arteries is cooled by the blood in the veins running alongside them.

Dolphins often jump out of the water, and this is thought to be just a sign of exuberance or *joie de vivre*. Actually, many a time they do so when escaping from a threat. The leaps are separated by short periods of rapid swimming just below the surface.

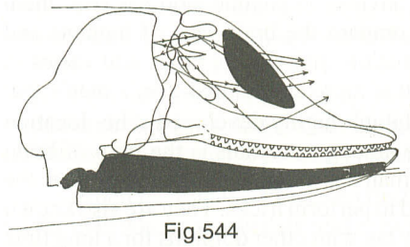


Fig.544

Echo location in dolphins. High-frequency sound is emitted by the lip of the nasal plug. Echoes are received by the lower jaw and transmitted to the inner ear.

Although it might seem that such jumping out and splashing back into the sea are a waste of energy, leaping is more efficient than continuous near-surface swimming at higher speeds. The "crossover" speed, i.e. the speed at which such action expends less energy per distance travelled, is about 10 knots (5 metres per second) for most dolphin species. Crossover speed increases with body size, since large animals have to expend more energy to lift their bodies from the water. Thus, large cetaceans like whales travelling at similar high speeds would not conserve energy by leaping.

Dolphins are gregarious animals. As many as 20 to 30 small groups can be found in a circle of 10 to 15 km diameter. These groups, numbering some 400 individuals may form a mating population; there are no harems. The single young is born, after a gestation period of 10 to 11 months, tail first (to avoid being drowned during birth). It immediately rises to the sea surface for its first breath of air. As among elephants, other females in the school take a lot of interest in the baby, solicitously guarding it from sharks and even suckling it. The milk glands do not protrude out of the body, but are recessed into grooves on each side of her genital opening. The calf does not have to suck; its mother just squirts the milk into the calf's throat.

Although their eyesight is good, dolphins– like bats– depend greatly on their remarkable sonar system (echo location). Both whistles used for communication and the clicks of echolocation are produced in the nasal-sac area located just below the blowhole. The sounds are produced when the blowhole is closed and air is moved past membranes that vibrate. The "melon", or fat body of the forehead, along with the concave shape of the skull in this area, acts as an acoustic lens and projects the sounds forward and upward.

Whales, dolphins and porpoises do not have external ears, and the ear canals leading to the middle ear are often obstructed. Sounds are detected via a different mechanism. Sounds are received through the mandible (lower jaw), and are channelled directly to the middle ears with the help of other fat bodies located on each side of the mandible.

A dolphin can produce a variety of sounds by shifting it between nasal sacs inside the skull, below the blow-hole. One variety is a repertoire of barks, bleats, clicks, mews, squawks, squeals, wails, whistles and yelps, made both above and below water. These seem to be a result of socio-emotional interactions such as fear, play, protest, threat. But it is the second kind of sounds called "rusty hinge" sounds– a pulsed ultrasonic series of clicks, which are a dolphin's eyes and ears. The dolphin does not hear through its pinhole-sized ear openings but through its jaw and throat. The clicks– as brief as three-ten thousandths of a second, but are produced in a long series of several hundreds per second. By means of these clicks, a dolphin can differentiate rock, flesh, and the resonating air bladders of fish. From the time-interval between a click and its echo, it can gauge its distance from the object. The sonar is so efficient that the dolphin can distinguish between two ball bearings of 51 and 63 mm diameter, or between two plates of the same size and thickness, but made of different metals. (Different metals produce different types of echoes.)

That dolphins are intelligent beings is obvious to anyone who has seen them perform in oceanariums. It is not proper to compare the brain size of humans and dolphins because of the great difference in function, and also as brain size varies in different species of dolphins. A dolphin's brain is more convoluted than a man's, but again much of this complexity is due to the dolphin's highly developed echo–location system. A measure of comparable intelligence among mammals is the ratio of brain weight to spinal cord weight. By this criterion man has about 20% advantage over the bottlenosed dolphin. Dolphins have been trained to perform tricks. They are also known for their playfulness and *joie de vivre*. They play tag with other dolphins for a long time without tiring, play with rubber balls and motor tyres. They frequently tease other animals; coming up behind a sleeping penguin, they will pull its feathers. Or lure a fish out of its hiding place by offering it a morsel of food, and then gulping the food when the fish comes out to eat it. As Ogden Nash so succintly puts it:

I kind of like the playful porpoise,
A healthy mind in a healthy corpus.
He and his cousin, the playful dolphin,
Why, they like swimmin' like I like golfin'.

Probably no other animal has been linked with man in legend and lore. Sailors from the days of Aristotle and Pliny have keenly observed dolphins and their habits and numerous tales– some factual, and some half-truths have gradually been woven around these animals. There are the legends of dolphins being attracted to music, carrying children piggy-back, or driving away sharks from shipwrecked sailors.

Fig.545 **Arion astride a dolphin**

Infuriated dolphins (and whales) are said to be lulled by music. Pliny the Elder has more than one legend to recount of dolphins. Arion, a notable musician and player of the cinthara (a kind of harp), was returning from Sicily to Corinth with the trophies he had won in some musical contest, when he chanced to fall in the hands of bad sailors who wanted to rob his money and throw him overboard. He besought them to allow him, before he died, to play a last tune on his harp. At the sound of music, a number of dolphins came flocking about him and, when Arion was thrown into the sea, one of them took him on its back and carried him safely to the Bay of Taevariis.

Then there is the legend of dolphins carrying people on their backs. During the reign of Augustus Caesar, a young boy staying at Baianum and going to school at Puteoli used to shout "Simo, Simo" repeatedly, when a dolphin would come and take him on its back.

Pliny also wrote of the fishermen from southern France as well as from the coasts of Mauretania near Cape Blanco, calling dolphins by shouting "Simo, Simo" whenever they wanted to herd mullet into their fishing nets.

Interestingly, fishermen along the coast of Santa Catarina state in Brazil, especially residents of the town of Laguna, catch mullet, croakers and black drum by using dolphins.

The fishermen line up parallel to shore in one-metre deep water. One or more dolphins take up a position several metres farther out, facing away from the men. As a dolphin dives, the men closest to it prepare to throw their nets. The dolphin usually surfaces in a few moments, heading straight towards the line of men but stopping just beyond their throwing range. The nets are then cast, fish are caught by both the dolphin and the fishermen, and the process begins once again.

When fishermen of Vietnam find a dead dolphin or whale, they bring it to shore, and the man who first saw it, is said to be the dead creature's eldest son. He has to wear a turban (as a symbol of mourning) for three months and six days, after which it is burnt. The bones of the dead animal are now placed in a depository bearing the name given only to tombs of royalty.

Although one may be inclined to pooh-pooh such legendary stories, there appears to be some truth in them. In New Zealand, around 1911, a dolphin inhabiting Pelorus Sound escorted every ship plying between Nelson and Wellington. In 1935, another dolphin, at Oponini Beach (New Zealand) used to play with bathers, allow them to pet and stroke it and allowed children to ride on its back. The government even passed a law to protect it, and it was a legend until its death in 1956. There is also a newspaper report of a man saved from drowning in the Gulf of Suez by dolphins which protected it from sharks and carried him on their backs. Since dolphins protect their own young from sharks by butting the shark on its tender belly with their beak, this account is not implausible. In fact, in an oceanarium in Australia one of the acts in the dolphin show is the simulated rescue of a drowning man by a dolphin.

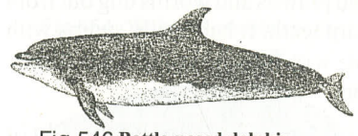


Fig.546 **Bottle-nosed dolphin**

Dolphins have been kept, and trained, since the early 1940s when the world's first occanarium came into being at St. Augustine, Florida (U.S.A.). The ones mostly kept are the bottlenosed dolphin (*Tiursiops truncatus*).

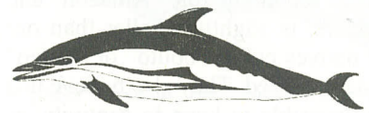


Fig.547 **Common dolphin**

The Common Dolphin (*Delphinus delphis*), also found in India, is cosmopolitan in distribution. It grows to 2·4 m, has a black or dark brown back and a white belly, these being separated by grey, yellow and white wavy bands. A black ring around the eye runs forward to the snout as a narrow streak. The 15-cm long narrow beak is sharply marked off from the low forehead by a V-shaped notch. There is no pronounced ridge on the tail.

Fig.548
Irrawady dolphin

Other dolphins recorded from India are the bottlenosed dolphin (*Tursiops truncates*), plumbeous dolphin (*Sotalia plumbea*), speckled dolphin (*Sotalia lentiginosa*), spinner dolphin (*Stenella longirostris*), black dolphin (*Sousa chinensis*), Irrawaddy river dolphin (*Orcaella brevirostris*) and broad-beaked dolphin [*Peponocephala* (earlier *Lagenorhynchus*) *electra*].

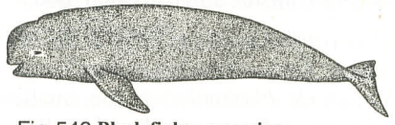


Fig.549 **Black finless porpoise**

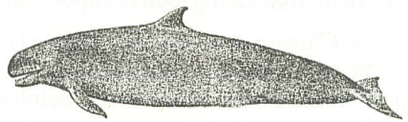


Fig.550 **False killer whale**

Among the porpoises we have in India is the black finless porpoise [*Neophocaena* (earlier *Neomeris*) *phocenoides*]. The false killer whale (*Pseudorca crassidens*) also occurs in Indian seas.

In the Tertiary Era, when the seas receded, several kinds of marine dolphins got trapped behind in rivers, and were adapted, over the years, to life in fresh water. Belonging to the family Platanistidae, there are four genera. All are distinguished from their marine cousins by the long, forceps-like snout and a low, rudimentary dorsal fin. Unlike the sleek and handsome marine dolphins which are admired for their playfulness and intelligence, the fresh water dolphins border on ugliness. They are beady eyed, humpbacked, long snouted and have a loose skinned appearance.

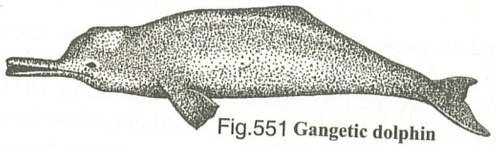


Fig.551 **Gangetic dolphin**

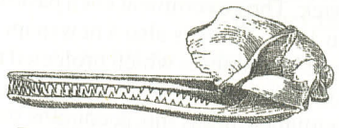


Fig.552 **Skull of Gangetic dolphin**

We have a representative in India– the *susu* or Gangetic dolphin (*Platanista gangetica*). Growing to 2·4 m, it is found in the Ganges and Brahmaputra rivers in India, Karnaphuli river in Bangladesh, and Indus river in Pakistan. (Some people consider the Indus dolphin as a separete species, calling it *Platanista indi*.) The body is lead black. Though diminutive eyes are seen, the dolphin is blind, there being no eye lenses. During the day it stays in the deeper parts in the turbid, almost opaque, river waters, but at night it comes into shallow water only 30 cm deep to hunt bottom dwelling fish and prawns and worms dug out from the mud and snapped up by the numerous needle-sharp teeth. It habitually swims with the body inclined to one side– generally, the right side with half the tail and one flipper out of the water. The *susu* is in dire danger of extinction.

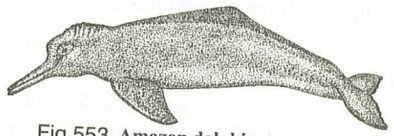


Fig.553 **Amazon dolphin**

The Amazon dolphin (*Inia geoffrensis*), found in the Amazon and Orinoco rivers, is slightly smaller than our *susu*. The natives call it "bouto" or "bufeo" and consider it sacred. They also believe that they are impossible to keep in captivity, as they would grow legs and walk away, or sprout wings and fly away! When the University of Florida expedition collected its first boutos in Colombia, the local military commandant stationed sentries around the holding pen to prevent their escape by these methods. They also believe that the dolphins disguise themselves as men to attract pretty girls and attend dances during carnival time. When an unmarried girl gets pregnant, the people believe that a dolphin is responsible, and the name "Bouto" is recorded in the birth certificate as its father!

Boutos have a grapefruit-sized hump on the top of their head, and often inflate these sacs with air for producing sounds. The young can emit echo locating clicks of sound right from their birth. Their eyes are well developed, but their bulging cheeks prevent them from seeing food on the bottom, so they turn upside down to catch food.

The Chinese or white-flag dolphin (*Lipotes vexillifer*) grows as large as the *susu* and is found in the Tungt'ing Hu lake, 960 km from the headwaters of the Yangtze Kiang. Tonina, or the Franciscana dolphin (*Pontoporia blainvillei*) is the smallest among fresh water dolphins, growing only to 1½ metres. It lives in the Rio de la Plata,

and is the only dolphin to have a symmetrical skull.

Cetaceans (whales and dolphins) are believed to have evolved from land mammals that returned to the sea during the Paleocene epoch about 70 million years ago. Marine and land mammals still have features in common. For example, many aspects of their internal anatomy, dentition and skull structures are comparable.

They appear to share an ancient ancestry with ungulates (hoofed animals). The first marine mammals appeared on the fossil record about 50 million years ago; they were poorly adapted for a totally aquatic existence.

Interestingly, the bottlenosed dolphin sleeps with only half of its brain asleep at a time, while the other half remains awake. After an hour or so, these roles are reversed.

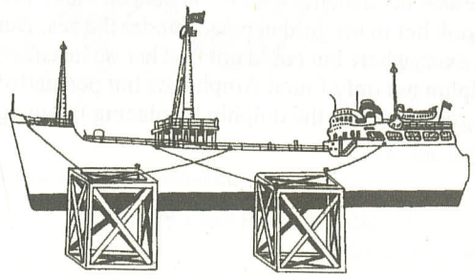


Fig.554 **"Dolphin" mooring posts**

Tailpiece:

You may see other kinds of "dolphins" in the harbour, but you will not even recognize them, because they are not animals. In fact, they are not even alive. Mooring posts, usually composed of groups of piles, driven into the bottom of a harbour, are called dolphins.

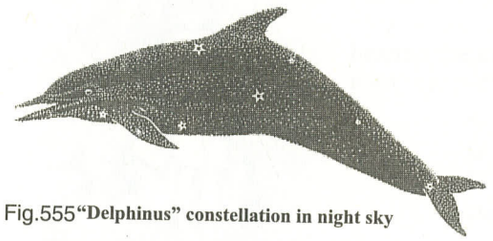


Fig.555 **"Delphinus" constellation in night sky**

Yet another dolphin that you can see is not in the sea, but in the sky. It is the constellation Delphinus, to the west of the Great Square in the constellation Pegasus. Indian astronomers call it the Porpoise constellation. There are two interesting mythological stories about its origin.

The more widely known story is about the celebrated Greek musician Arion, who lived in 600 B.C. He was famed as the finest cithara (lyre) player in the whole of Greece. Once he travelled to Sicily to take part in a music contest. He won the competition and received many gifts. To return home, he hired a ship to take him across the Ionian Sea to Corinth, his native city. After they set sail, the crew decided to throw him overboard and steal the valuable gifts that he had won. They would, on reaching Corinth, say that he had been lost in a storm at sea.

When Arion learnt of the plot, he begged the crew to let him play his cithara one last time, after which he would jump into the sea. The crew agreed, so Arion went to the bow of the ship and began to play. As he played his beautiful music, the birds of the air and the fishes of the sea came near to listen. Dolphins also gathered near the ship to listen to his music.

At the end of his song, Arion leaped overboard as he had promised. He had barely hit the water when a dolphin rose beneath him and carried him to shore. After safely depositing him on the shore, the dolphin returned to the sea.

Arion made his way across the land to Corinth, arriving before the ship had made port. He narrated his tale to Periander, the tyrant of Corinth. When the ship arrived, Periander asked the crew where Arion was, and they reported that he had been lost overboard. Arion then stepped forward. The crew were amazed and admitted their guilt.

As thanksgiving for his miraculous rescue, Arion had a bronze statue made depicting him being carried by the dolphin. (See Fig.555.) He presented the statue to the shrine of the sea god Poseidon at Taenarum. The gods honoured the dolphin by placing its likeness and Arion's lyre among the stars.

The other Greek story explaining the dolphin's presence in the sky has to do with the dolphin that helped the sea god Poseidon. According to legend, Poseidon fell in love with the sea goddess Amphitrite when he saw her dancing with her sisters on the Greek island of Naxos. He kidnapped her and took her to his golden palace under the sea. But Amphitrite ran away. Poseidon searched everywhere but could not find her, so he called one of his dolphins to help him. The dolphin not only found Amphitrite but persuaded her to become Poseidon's wife. The sea god rewarded the dolphin by placing it among the stars.

74 Mermaids with Moustaches

I never saw a purple (sea) cow,
I never hope to see one;
But I can tell you, anyhow,
I'd rather see than be one.
Adapted from Gelett Burgess

My dreams had finally come true; I was face to face with a mermaid or, more accurately the creature that has given rise to the legend of mermaids.

And what a climbdown it was! From my boyhood I had been hearing tales of extremely beautiful maidens with long, streaming hair and voluptuous bosoms, human down to the waist, but with the lower half of the body covered with scales and ending in a fish-like tail.

The Greeks and Romans called them sirens or nereids, and they (the sirens, that is) sang so enchantingly that any sailor hearing them was bound in a bewitching spell, and jumped into the sea to embrace them and drowned. Ulysses had to plug his sailors' ears with wax to prevent them from hearing the sirens' songs, and he tied himself to the mast so as not to jump into the sea to his doom.

Fig.556
An illustration from "the Little Mermaid" by Hans Christian Anderson typifies the popular concept of mermaids

Good reader, if you e'er have seen,
When Phoebus hastens to his pillow,
The mermaids, with their tresses green,
Dancing upon the western billow
Thomas Moore

And what did I actually see? A sausage-shaped body some 3 metres long and weighing– may- be– half a ton, with thick greyish-brown wrinkled skin, small beady eyes and a horizontal notched tail. Between the short flippers springing from the shoulders, rounded at the ends and without any nails, were two tiny, 3-cm long teats the length of one's thumb, indicating that it was a female. The mouth, to say the least, was not kissable. The upper lip was in the form of a horseshoe-shaped muzzle, divided into two swollen pads which bore stiff, quill-like bristles.

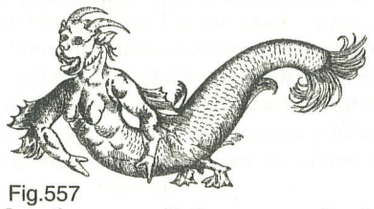


Fig.557
Just as there are mermaids, there are mermen. Above is Triton, the mythical son of Poseidon and Amphitrite

How could any person compare this to a beautiful mermaid? The female is said to suckle her young while clasping it with a flipper to her bosom just like a woman cradling her baby in her arms. Probably a love-sick sailor in a slow sailing ship out on a long voyage lasting many months, saw one in the dim moonlight and let his imagination run riot. I can sympathise with him as I too have had this experience. We were

out on an oceanographic ship. There were no women scientists or crew on board, and it was a month before we touched port in Africa. To complete customs formalities, two women customs officials came on board. A scientist lolling on the deck saw them and excitedly ran down to inform all of us in our cabin. In a trice, almost all the scientists (including me) went up to have a closer look. And remember, this was only a month away from the company of women!

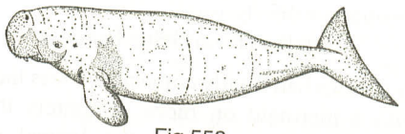


Fig.558
Dugong [*Dugon Halicore* (formerly *dugong*)]

The dugong (*Halicore dugong* or *Dugong dugon*)– for that is the animal I am talking about– is a large mammal 2·5 to 3·5 metres, distantly related to elephants.

I will go back to the great sweet mother,
Mother and lover of men, the sea.

Swinburne

It is found in the seas close to the shore from East Africa and Madagascar, up the Red Sea, India, Sri Lanka, Bangladesh, Myanmar, Malaysia and Indonesia to North and West Australia and the Great Barrier Reef. Northward, it extends to Formosa, Japan, Philippines and eastward to New Guinea and some of the islands in southeastern Micronesia in the Pacific Ocean (Caroline, Solomon, Marshall Island and New Caledonia).

In India, it is found in the Gulf of Kutch, Gulf of Mannar and the Andaman Islands. In fact, in the Little Andaman group there is a place called Dugong Creek. Jerdon, in 1894, wrote that they were reported (but mistakenly as seals) from islets off the South Malabar coast of Kerala. The Mesolithic peoples of the area now called Gandhi Sagar in Rajasthan, about ten thousand years ago painted dugongs on the walls of their cave dwellings. Today this place is more than 200 km from the sea, but it should be remembered that Saurashtra was then not attached to Gujarat, and much of Rajasthan was then covered by sea; even the valleys of rivers Indus and Luni were then marine.

The word 'dugong' comes from the Malay word "duyong". Dugongs are completely vegetarian and consume sea grasses (such as *Zostera, Thalassia, Thalasodendron, Syringodium, Halophila, Halodule, Enhalus* and *Cymodocea*). The plants are grasped between the pads of the muzzle and crushed between horny plates in the jaws, finally being ground by the five pairs of upper cheek teeth and five lower molar teeth. The males have a pair of down-pointing long tusks (incisor teeth) some 23 cm long; these are absent in females. In captivity, they feed readily on water hyacinth, lettuce and cabbage leaves.

Being a mammal, it breathes air and has to come up to the sea surface every 1½ to 4 minutes. The crescentic nostrils are close to the muzzle, right on top; they can be closed by hinged valves when the dugong dives under water. There are no hind limbs. A pair mates for life and the single young (rarely twins) is in the mother's womb for 13 to 14 months. The baby is about a metre long at birth, weighs some 20 kg and suckles for a year and a half; the milk is very thick, like condensed milk. In the lactating mother, the teats elongate to 8 cm.

The dugong is a most inoffensive animal. When threatened, it will swim away at a speed of 18 to 20 km per hour, but soon tires. The male's tusks are not used against an enemy; they probably help it to root out its food. Dugongs live up to 20 years, but rarely attain this age. They are not eaten in Gujarat. The predominantly Muslim population there call it "soover machchhi" (pig fish), and pig's flesh is forbidden in their religion. They also call it "bai maanas" (a woman) or "loolee" (a crippled woman). But they use its oil for applying on their wooden boats for preventing wood-borers. In South India it is ruthlessly

hunted for its skin, fat and meat, which tastes like veal or pork. This taste has given dugongs their other name– sea-cow. The native Onges of the Andaman Islands hunt them in Ritchies Archipelago and North Reef.

The animal is hardly seen nowadays, usually alone, but herds of 15 or more individuals are sometimes met with. It is an endangered species and catching it is banned. It is more fortunate in Australia, where large herds can be seen even today.

I would be the last person to harm a dugong, but I was witness to a bizarre incident many years ago. It makes a poignant story. The venue was an agriculture fair, and the host state serendipitously managed to catch a live dugong just a few weeks before its inauguration. To house this *piece de resistance*, they constructed a huge pool– almost a miniature swimming pool, and put the animal in it. A VVIP, being told that the dugong's mammae are like a woman's breasts, wanted to satisfy his curiosity. Now a VVIP's request is tantamount to an order, so the officials wanted to please him. But the dugong being modest, would not oblige by turning on its back. They prodded it with poles, and the animal decided that enough was enough. She swam at full speed, rammed her head against the concrete walls of the pool and died. And that was the sorry end of the sea- cow!

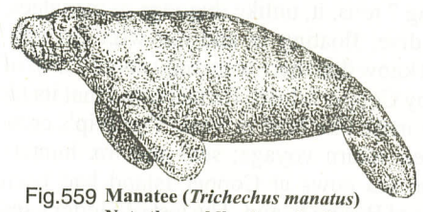


Fig.559 **Manatee (*Trichechus manatus*)**
Note the paddle-shaped tail

Cousins to the dugong are the manatees. There are three species; the American manatee (*Trichechus latirostris*), found in Florida, U.S.A., off the Caribbean Islands, Mexico and northern Brazil, the West African manatee (*T. senegalensis*), and the freshwater *T. inunguis* found in some Amazonian rivers of northern South America. The American manatee is 2½ to 3¼ metres long, and can be distinguished from dugongs by its rounded paddle-shaped tail, flat nails on the flippers, no external ear-holes and up to 20 cheek teeth on the jaws. Though the male has no tusks, it can be easily made out as its genital opening is located far forward, close to the middle of the belly, while the female has it near the anus. While both the American and West African manatees have nails on the pectoral flippers, these are absent in the freshwater Amazonian manatee.

Manatees may weigh 900 kg and feed up to one-tenth of their body weight of sea grasses every day. They are less marine than dugongs and may ascend rivers and love to drink fresh water from pipes or streams entering the creeks. They breed at 4 years and bring forth a calf every 2 to 3 years. They emit squeaks, especially when alarmed, but these are not used for echo-location as by dolphins.

Manatees have a bristled muzzle, and Christopher Columbus remarked that they were not as beautiful as they were painted out to be, although to some extent they have a human appearance in the face.

Manatees have to cope with excessive wear of the teeth due to gritty substances such as sand that are often eaten along with their food They continually lose teeth and replace them with new ones. New teeth are formed in a pocket known as the alveolar bulb, which is located far back on both sides of the upper and lower jaws. As new teeth emerge from the pocket and slide forward into position, the old teeth are shed from the front. As the old teeth get ground down their roots are reabsorbed.

Such replacement is not found in dugongs. The dugong possesses permanent teeth that grow continually. As the crowns of the teeth are worn down, new material is deposited at the roots.

Fig.560

Steller's sea cow depicted on a chart attributed to Sven Waxel, (1741)

Fig.561

Steller's men study a sea cow. (From Bering Voyages, Vol. II, by F.A. Golder, American Geographical Society)

There used to be a third representative of the Sirenia (the group comprising dugongs and manatees) but, alas! it is no more. Human rapacity put paid to it. This was the Steller's Sea Cow (*Hydrodamalis gigas*), named after the German botanist George Wilhelm Steller, who took part in Vitus Bering's second Kamchatkan Expedition of 1741, ordered by the Russian czarina to determine where America lay relative to Asia. His ship, *St. Peter*, took shelter in the then uncharted Bering Island. Steller saw huge creatures, looking as if the head and tail were stuck on to a bulbous body. With a length of 7 metres and weighting 7 tons, it, unlike dugongs or manatees, did not dive, floating in and out with the tide, feeding on plants torn off rocks. Steller did not know that there were only about 1,500 of them, restricted to Bering Island and the nearby Copper Island. He has noted that its fat tasted like the oil of sweet almonds, and the meat like beef or veal. The ship's crew started butchering them as provision for their return voyage; seal and fox hunters continued the slaughter and by 1754 all the sea cows at Copper Island had been exterminated, soon to be followed by the herds of Bering Island. The last of Steller's sea cows died in 1768.

The most hilarious letter that I have ever received in my chequered career is either from a crank or someone with a huge sense of humour.

The person does not reveal his name, but introduces himself as Mr. Mark Ringling Nixon, Proprietor Mark Ringling Nixon & Co. Inc., Merchants & Order Suppliers to World's First Ten Richest Women, Men, Nobel Prize & Lottery First Prize Winners only. (This is followed by an address, of which I shall give only the beginning, C/o Sibu, Canteen, ... (of a college).

The letter runs as follows:

25.4.1973

Dear Honoured Sir,

I shall deem it a great favour if you very kindly send me some marine cucumber per Value Payable Parcel for Rupees ten on 26th positively as referred to your illustrated catalogue or small booklet about your Aquarium. It says it is a great medicine for all stomach trouble.

Please send me at least 3 copies of illustrated catalogs or books with prices, per airmail, registered post with receipt on 26th regarding Aquarium, to demonstrate & take order on your behalf, as your monopoly agent for 50 years, throughout the world. Please send 3 copies of appointment letter stating pay, world touring travelling allowances, including your calendar & books in all languages of the world.

If you send me even a third class railway fare, by express telegraphic money order I am prepared to work at your Aquarium as a gateman or a ticket seller.

Can electricity be produced by Electric Eeel, which has got 6,000 volts? I wish to produce electricity from Electric Eeel.

What's the very lowest price of one pair of full grown, male and female Electric Eeel, their weight & sending charges, keeping them alive. I have no marine water here. If I keep them in salted water will they stay alive? What to feed them. If it is not possible to produce electricity from Electric Eeel, I am prepared to stay at the Aquarium for 50 years.

Have you got mermaids, send special photo or illustrated catalogue of mermaid. If you have not I shall try to produce artificial mermaid by joining the lower portion of a fish to a woman who lost lower portion of her body in railway or motor accident. Where to see & purchase mermaids & at what price? I wish to change Chilka lake of Orissa as your branch Aquarium.

Yours faithfully,
Mark Ringling Nixon,
Professional Artificial Rainbow
& Rain Maker,
C/o. Sibu, etc.

Acknowledgements

To cope alone and unaided with a subject so vast and complex as the sea would be, in the least, a daunting task. This book would not have seen the light of day but for the wholehearted and unstinting assistance of many people. On every hand I have been given the most friendly help by many persons who gave their time, material and information generously. It is only fitting that I express my gratitude to them.

The seeds of this book were sown when Dr. Jay S. Samant, Head, Department of Environmental Science, Shivaji University, Kolhapur, Dr. Pratap R. Saraiya, trustee of Mehta Scientific Education & Research Trust, and Professor P.V. Bole, former Head of Botany Department, St. Xavier's College, Bombay, among others made a suggestion to me to write a book more comprehensive than my earlier books on marine life.

Dr. V.M. Meher-Homji, former Dean, Salim Ali School of Ecology, Pondicherry University and Director (Research) of the French Institute, Pondicherry readily agreed to write the foreword.

The library resources of the Taraporevala Aquarium and Bombay Natural History Society libraries have been placed freely at my disposal, and my special thanks are due to Shobhana G. Mobharkar, Deepali D. Patil, librarians at the Putlibai Taraporevala library, and to Shubhangi M. Vedak, Smita V. Surse, and N.V. Dighe, librarians, and library assistants Tarendra Singh and Sadanand Shirsat at the BNHS library. Their tireless efforts and thorough knowledge of the available literature have been unfailingly helpful. I also thank Rivka Israel for lending me valuable books from her personal collection.

Many others have gone to great trouble to help me. I am especially grateful to the following:

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Dr. Gayatri Ugra, assisted by Jomini Georgy, Vibhuti M. Dedhia and Divya Fernandez greatly facilitated the planning and preparation of this book by editing it, fitting illustrations into the text and dealing with the nitty-gritty and minor irritations that usually crop up during the preparation of a book. J.P.K. Menon did the layout and formatting of the book assisted by V. Gopi Naidu.

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A few of the invertebrate animals in the colour photographs were collected by Mou Ghosh. Many others were collected by S.R. Sane and the author and photographed by the two of us assisted by R.D. Padte.

The coral reef fishes were collected by Rodney Jonklaas and the author by Scuba diving off Sri Lanka and were photographed by the author. Deepak Apte identified many of the sea-shells.

I am most grateful to the original authors and publishers of many of the figures and have, wherever possible, acknowledged them alongside each of these.

Dadi Poonawala of Comart Lithographers Ltd. organized the scanning of the colour photographs. Tripan Bannerjea of Manjushree (D.T.P. Div.) designed the collage of the frontispiece and scanned the black-and-white illustrations.

I would like to express my grateful thanks to all the above persons for collectively contributing to the preparation of this book. And my sincere apologies to those whom I may have inadvertently missed acknowledging.

Finally, I feel that any writer on natural history owes his biggest debt of all to the plants and animals that furnish the material for his work, and which give the Earth so much of its splendour. It is for once true to say, in the well-worn author's cliché, that without them this book could never have been written.

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Glossary

Aboral –opposite end to the mouth end; opposite of oral.
Acoelomate– an animal without a body cavity (except the gastro-vascular cavity)
Analogous– parts that have similar functions but have different evolutionary origins, e.g. the wings of insects and birds.
Anterior – towards the head.
Apolysis– separation of the cuticle (outer skin) from the underlying layer (epidermis) at the time of ecdysis (moulting), in arthropods.
Benthos– living on or in the sea bottom.
Brachial – refers to an appendage (a limb).
Branchial– refers to the gills.
Buccal cavity– the cavity next to the mouth.
Carapace– a hard dorsal shield covering the whole or part of the body in arthropods.
Caudal– refers to the tail or posterior part of the body.
Cephalic – refers to the head or towards the head.
Cephalothorax– the combined head and thorax (chest) in arthropods.
Chela or **cheliped** – pincer-like claw in crustaceans.
Chitin – the tough cuticle (chemically a polysaccharide) in arthropods and other animals.
Chromatophore -a pigment-containing cell.
Cilium (plural cilia)– a short, hair-like process, arranged in rows or groups, in ciliate protozoans and other animals.
Cirrus – a slender, variable appendage in many invertebrates.
Cloaca – the rear end of the digestive tract.
Coelenteron – the gastro-vascular cavity of radiate animals.
Coelome – internal body cavity, lined with peritoneum, found in higher invertebrates.
Collocyte – the adhesive cells of ctenophores.
Colony – a group of genetically identical asexually produced individuals living cooperatively together.
Commensalism – a relationship where one species (the commensal) benefits while the other species (the host) is not affected.
Compound eye – an eye made of many visual units (called ommatidia) producing a mosaic image (in arthropods).
Crore – 10 million.
Cryptobiosis – a state of suspended animation induced by desiccation, occurring in nematodes and rotifers.
Cteniduim – the gill of molluscs.
Cuticle – the thin, non-living external covering (skin) of invertebrates.
Cyst – a resistant protective covering produced in response to desiccation.
Detritus – fine particulate debris, consisting of fragments of plants and animals.
Dextral– right handed (the direction of coiling in gastropod molluscs)
Diapause – a light or temperature-induced state of developmental arrest.
Dimorphism – existing as two distinct forms.
Distal – away from a point of reference (opposite of proximal).
Dorsal – towards or referring to the back or upper side.
Ecdysis – moulting (shedding) of the old cuticle in arthropods.
Ectoparasite – a parasite attached to, or living on, a host's outer surface.
Endoparasite – a parasite living inside the host's body.
Endoskeleton – a skeleton contained inside the body (as in sponges and echinoderms)
Epidermis – the outermost cellular layer (skin) of animals.
Evert – to turn inside out (like a glove's finger).
Exoskeleton --a skeleton found outside the body, as in arthropods and molluscs.
Exuvium – the cast-off exoskeleton after ecdysis.
Filter-feeder --aquatic animals feeding on floating particles.
Flagellum – a long, thread-like, locomotory organelle.
Gamete – a (haploid) sex cell – a sperm or an ovum.
Gizzard – part of the foregut specialised for grinding food.
Gravid – filled with fertilised eggs.
Herbivorous – an animal feeding on plants.
Hermaphrodite – an individual having both male and female reproductive organs and systems.
Heterotrophic – animals requiring feeding on organic matter (opposite of autotrophic plants, which can synthesize food from inorganic matter.
Homologous – parts of body which have a common ancestral origin (but may have different functions).
Host – an organism on or in which a parasite lives.
Indirect development – animals having a larval stage.
Integument – the skin or outer covering of an animal.
Instar – the period between two consecutive moults. (Refers to the animal and not the time.)
Lakh – 100,000.
Larva–a stage during the growth of an animal where it looks different from the adult.
Lentic– refers to standing water bodies, such as lakes or ponds.
Littoral– the shallow coastal region of a sea.
Lotic – refers to running water such as rivers or streams.
Mantle – an extension of the body wall covering the internal organs which, in molluscs, secretes the shell.
Metamere – a segment, one in a series in segmented animals.
Metamorphosis –a substantial change in body form during growth.
Micron or Micrometre – one-millionth of a metre.
Moult – to cast off or shed the outer cuticle.
Monoecious – hermaphrodite; an organism with both male and female organs. (Opposite of dioecious).
Mutualism – a relationship between two different animals where both benefit by the association.
Necton – animals which can swim powerfully enough to breast currents, such as fish, squid, turtles and whales.
Neotony– where the larval characters of ancestors become adult features of their descendants.
Nocturnal – active at night.
Ocellus – a simple eye, made of a cluster of photoreceptors.
Omnivore – an animal feeding on plant as well as animal matter.
Ontogeny – the development of an individual.
Operculum – a flap-like covering of gills in arthropods, or of the shell aperture in gastropod molluscs.
Oral – refers to, or near, the mouth.
Osmoregulation – the maintenance of the osmotic concentration of body fluids at a level different from that of the surrounding water.
Oviparous – egg-laying animals.
Ovoviviparous – where the eggs develop inside the mother's body, but are not supported by nutrition by the mother.
Papilla – a cone or nipple-like outgrowth.
Parasite – an organism living on or in, and deriving nutrition from another organism (the host).
Parasitism – an association of two organisms where the parasite benefits at the expense of the host.
Parthenogenesis– where an organism develops from an unfertilised egg.
Peduncle – a stalk supporting another structure.
Pelagic – living in the open sea.
Phylogeny – the evolutionary history of a group of organisms.
Plankton – plants and animals which cannot swim powerfully and therefore drift with the currents.
Polymorphism – where there are two or more morphological forms during the life cycle of an animal.
Polyp(e) – the sessile, conical, asexually reproducing stage in coelenterates.
Polyphyletic – a group of organisms evolved from more than one ancestral source.
Posterior – towards the rear (hind) end.
Protandry – where, in a hermaphrodite, sperms are produced before the eggs.
Proximal – nearer a point of reference (opposite of distal).
Radial symmetry – where similar parts are arranged around a central axis.
Radula – a file-like, toothed ribbon which can be thrust out from the buccal cavity in gastropod molluscs.
Ramus – a branch or outgrowth of any structure. (Plural rami).
Raptor – an animal which stalks and captures prey for food.
Sedentary – sessile; an animal which remains in one place.
Septum – a membranous partition separating two cavities, in coelenterates and annelid worms.

Seta (or **cheta**) – a continuous bristle, found in annelids.
Sinistral –left-handed.
Species – a taxonomic unit of similar organisms which can interbreed producing fertile progeny.
Spermatophore –a packet of sperms which can be placed on the female.
Statocyst – a sense organ for detecting an animal's positions or orientation with respect to gravity.
Stridulation – producing sound by rubbing the parts of the body together.
Symbiosis – intimate association of two organisms of different species living together.
Test – shell-like skeleton of some protozoans and sea urchins.
Tubicolous –building and/or living in tubes, as in annelids.
Ventral– towards or referring to the lower surface.
Viscera– the internal organs of an animal.
Viviparous – where the young develop inside the mother's reproductive tract and are also nourished by her before birth.
Zooid – the individual member of a colony of coelenterates and polyzoans.
Zooplankton– the animal component of plankton (as against the plant component–phytoplankton).

Appendix

Note for Advanced Biologists

Classification is the arrangement of a number of diverse organisms (or even inanimate objects) into larger or smaller groups, based on their likeness or dissimilarities to each other. The lay reader will, many a time, be confused by the different classifications adopted by different authors. Even among systematists, debate continually rages on the merits (or otherwise) of a particular scheme of Classification. It is felt, in this book, to leave aside classification altogether, in order not to confuse the reader. Some classifications are based on comparative anatomy. while others lean heavily on systems, i.e., those in which organisms are grouped according to (what is thought to be) their natural affinities. While some of these may be of great value to advanced biologists, some other scheme would be more suitable to those who merely wish to acquire general but nevertheless systematic knowledge of biology, even though such classification may appear to be a little simplistic to the advanced specialist.

There are about 1 million species of plants and animals.

Animal species number over 1,100,000; of these the vast majority (1,070,000) are invertebrates (i.e., without backbones), only 3.4% being vertebrates.

At a cursory glance, we divide living forms into plants and animals. Plants are autotrophs, i.e., they can manufacture their own food from inorganic chemicals such as $H_2 0$ and CO_2. They are non-motile, they do not move from place to place, and hence confront the environment equally from all directions. Against this. animals are (mainly) mobile, only a few being sessile. They are heterotrophs, depending on organic material living (or once living) things – for food. They usually have an anterior (head) end meeting the environment first, before the rest of the body. They also usually have a ventral (under) surface next to the substratum (bottom). And they also have a nervous system responding to stimuli, some means for circulating food and air and for getting rid of waste products such as ammonia, urea and uric acid.

But not all organisms fit conveniently into this simple classification. There are primitive organisms such as the green flagellates, e.g. *Euglena,* which are auitotrophs like plants, but move about like animals. And both botanists and zoologists claim them in their scheme of classification. To bridge the gap a scheme consisting of five kingdoms has been worked out based on phylogeny– the process of establishing the evolutionary history of a group of organisms. The kingdom Monera comprises the bacteria and blue-green algae. The next kingdom is Protista, comprising the eucaryotes, i.e., forms with a cell nucleus with nuclear membrane and well developed membrane-bounded cytoplasm. In this kingdom are included slime moulds, green algae, diatoms, Dinoflagellates, euglenophytes and protozoons. Fungi constitute the third kingdom, while Plantae and Animalia complete the total.

Subsequently, G.F. Leedale in 1974 modified the earlier scheme to form only four kingdoms by including the slime moulds in fungi, clubbing the dinoflagellates, euglenophytes, green algae and diatoms with Plants. and the Protozoa with Animals thus eliminating the kingdom Protista.

As stated earlier two taxonomists rarely agree on a uniform scheme of classification. Names keep changing and taxa are removed and regrouped as evolutionary and phylogenetic discoveries demand. For example, the crustacean subclass Mystacocarida is based on animals discovered in 1943, two other classes– Cephnlocarida and Remipedia in 1954 and 1980 respectively and even a new phylum Loricifera as late as 1983. Thus almost every student of zoology is familiar with Protozoa as a Phylum. But in the last three they have been elevated into a group –something like a superphylum – what were earlier Classes now being Phyla. The result is that the term Protozoa is used today as a collective noun, but

without the status of a phylum which it once held. The former Class Sporozoa is now divided into four new phyla, viz. Apicomplexa, Microspora, Ascetoepora and Myxozoal (classification of Levine *et al.*, 1980). The Crustacea have been elevated from an earlier Class to a Subphylum

A few terms need explanation as also classification rests principally on these features.

Major phyla are those having more than 5,000 species; the rest are minor phyla. Shortly after fertilisation, the zygote (fertilised egg) divides into many cells called blastomeres. In one group– Deuterostomates, each of these cells, in the early stages of development can, if separated from other blastomeres, produce a complete embryo. In the other group called Protostomates, however, after the first cleavage (division of the zygote into two cells), each of the two blastomeres can develop only into a predetermined half of the embryo. The coelome is a cavity inside a (coelomate) animal's body which is developed within the mesoderm and is bounded by layers derived from the mesoderm called peritoneal lining. Acoelomate animals do not have a body cavity; there is a solid mass of mesodermal cells and muscles (which are derived from the mesoderm).

Pseudocoelomate animals have a body cavity, but this has no mesodermal (peritoneal) lining.

Lophophore is a food-gathering organ bearing a circle of hollow ciliated tentacles surrounding the mouth.

Metamerism is the phenomenon in which an animal's body is divided into a series of segments (metameres or somites).

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